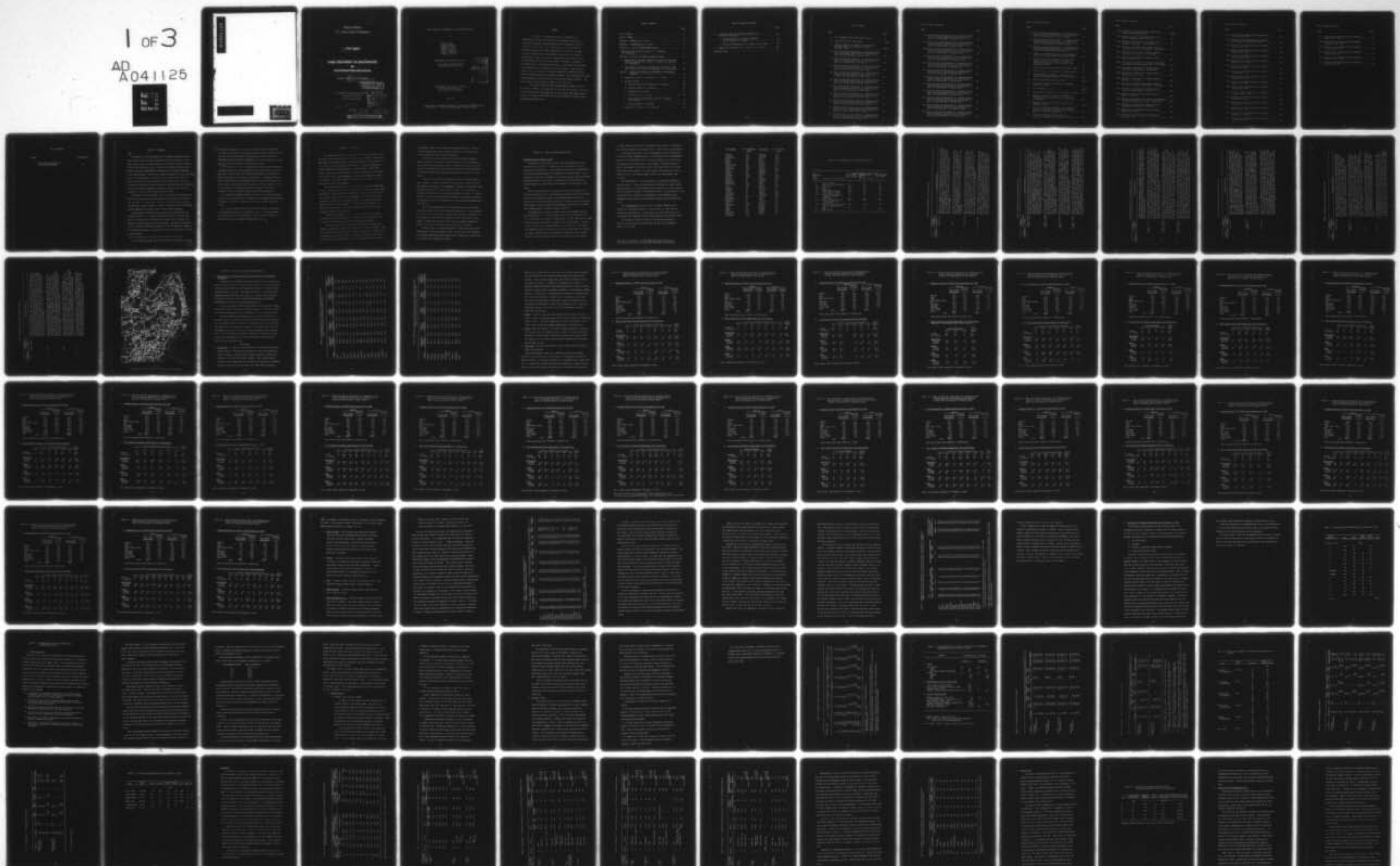
AD-A041 125 MICHIGAN STATE UNIV EAST LANSING DEPT OF CROP AND SO--ETC F/G 13/2
LAND TREATMENT OF WASTEWATER IN SOUTHEASTERN MICHIGAN.(U)
JUL 73 DACW35-73-C-0163

UNCLASSIFIED NL

1 OF 3

AD A041125



ADA041125

1

Detroit District

U.S. Army Corps of Engineers

9 **final report**

6

LAND TREATMENT OF WASTEWATER
IN
SOUTHEASTERN MICHIGAN

15

CONTRACT NOS. DACW 35-73-C-0163 to 0170

DACW35-73-C-0170

DEPARTMENT OF CROP & SOIL SCIENCES
Michigan State University
East Lansing, Michigan 48223

410248 New

JUNE 1973

11 Jul 73

12 239p.

LAND TREATMENT OF WASTEWATER IN SOUTHEASTERN MICHIGAN

By

Boyd G. Ellis
A. Earl Erickson
Bernard D. Knezek
Raymond J. Kunze
Ivan F. Schneider
Eugene P. Whiteside
Arthur R. Wolcott

Department of Crop and Soil Sciences

Ray L. Cook, Professor Emeritus
Department of Soil Science

Department of Crop and Soil Sciences
Michigan State University
East Lansing, Michigan 48823

June 1973

Final report in partial fulfillment of Contract Nos. DACW35-73-C-0163 to 0170 for U. S. Army Corps of Engineers, Detroit, District.

PREFACE

To develop a land disposal system for wastewater for a municipality as large as Detroit is most challenging. The group of scientists who worked to develop this report are specialists in each of the areas of soil science. But to develop such a system requires an integrated overview to be able to make accurate projections. And many of these projections must be made without the benefit of well defined research data. This is a new area. Application of high rates of water to fine-textured soils has not been studied in Michigan or elsewhere in the United States. Consequently, many areas of this report were developed as a cooperative effort between two or more individuals. This was particularly true of the sections on projected conditions in 1985 with irrigation and cropping systems and irrigation schedules. Those principally involved with development of these sections are listed in the table of contents. But in each case the total group had inputs to the projections.

The authors would also like to acknowledge the major effort of Dr. Delbert L. Mokma, of the Department of Crop and Soil Sciences, a specialist in soil classification with experience in soil chemistry and remote sensing; and also Mrs. Betsy Bricker whose services were obtained to facilitate data collection and organization.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

List of Tables (Continued)

List of Tables (Continued)

List of Tables (Continued)

List of Tables (Continued)

List of Tables (Continued)

LIST OF FIGURES

SECTION I - ABSTRACT

The purpose of this investigation was to assemble and interpret data which could be used to develop irrigation zones for the purpose of wastewater utilization by land application as an alternative method of treating effluent from the Detroit area. A compatibility between wastewater applications and effective agricultural production was an essential component of all considerations. Various soil parameters appeared to be the controlling factor in the development of irrigation zones, and the basic units from which the zones could be constructed were soil associations. Each soil association contained soil types with similar irrigation potential properties. To allow for maximum flexibility in defining irrigation zones, data was tabulated for each soil association within each county.

Information for the assessment of existing conditions was adapted from county soil survey maps, aerial photographs, Conservation Needs Inventory data, and 1969 U. S. Census data. Data from the 1985 projections made by the experiment station was used to estimate the change in land use and agricultural production that would evolve by 1985 without irrigation.

Certain phases of Michigan agriculture must be compatible with any irrigation project. For example, more than 95 percent of the navy beans grown in the United States are grown in the Thumb area of Michigan. The operation of this enterprise must be maintained. The sugar beet industry, as well, could not reasonably be phased out. But the agriculture industry in Southeastern Michigan could utilize both the water and nutrients carried in waste effluent.

The following major conclusions were reached in this study:

1. The principal crops that will be grown under irrigation in

next page

cont

Southeastern Michigan are: a. corn; b. beans (this will include both navy beans and soybeans with location controlling which is grown); c. wheat and other small grains; and d. alfalfa-brome hay. Other crops such as sugarbeets will be grown with irrigation but the total acreage of all other crops will be small compared to the four listed above.

2. Major problems may be encountered with both percolation rates and drainage of some of the fine-textured soils in certain areas. For example, many soils in Huron County are underlain by impermeable till which will reduce the quantity of water that can be applied. In addition, this till may preclude placing the tile drainage lines at the five-feet depth. For these soils the conclusion reached was that 12.5 inches of water per acre per year would be the maximum that could be applied. This would be designed to offset the moisture deficit during the summer months.

3. Phosphorus adsorbing capacity of the soils will only limit application rates on the sandy soils. In these cases the application rate should be limited to 40 inches of water per year if the phosphorus content is 7 ppm P.

4. The total application of water in the Southeastern 25 counties is approximately 68 million acre inches per year. This would mean that more than one-third of the potentially available area would need to be developed to receive wastewater from the Detroit area.

SECTION II - INTRODUCTION

The national objective to clean up the environment, including streams and lakes, has made people realize that wastes can no longer be dumped into open waters or be channeled into underground aquifers. Serious problems, in this respect, are facing municipalities where raw sewage or inadequately treated effluent from treatment plants is being allowed to enter public waters. Even effluent after adequate secondary treatment is still nutrient rich and will lead to rapid degradation of streams and lakes that receive this material. The growth response by algae and other aquatic life to the nutrients has been well documented.

Soil has long been known as nature's most effective decontaminating facility. Dead animals have been buried and animal manures have been spread and worked into the soil from time immemorial. Thus, plant nutrients have been recycled and essential soil microorganisms fed. Soil structure was maintained or improved by the organism activity and nutrients were held against leaching. Always, however, it was essential that additions of waste were not excessive. The farmers learned this by experience, and Experiment Stations by field research.

Hydrologic and chemical studies of soil, made possible by modern instruments and testing methods,have established certain parameters that may be used in outlining permissible soil management practices.

Municipal sewage may be "cleaned up" by passing it through three stages, 1) aeration to oxidize organic matter, 2) settling to remove solids, and 3) finally a tertiary process to remove substances from solution. One alternative for the tertiary process is that of using soil as a "living filter," with crop production as a means of removing from the soil some of

the nutrients added in the wastewater from sewage processing. This has an added advantage over other tertiary processes in that nutrients are recycled immediately back into food production.

Soils vary as to the amount of water they can absorb during a season's growth of a particular crop, and crops vary as to the amount of water they can tolerate without injury. Likewise soils vary in the total amount of certain nutrients they can adsorb (remove from solution) before they become saturated and thereafter are unable to function as a "living filter."

Weather records show that Michigan rainfall in the summer months is quite irregular. Drouths of greater or lesser severity occur every year. Many farmers are making use of supplemental irrigation for high value crops. and others would do so if costs were not so high. Also, many acres of Michigan's farmland can be improved by more adequate drainage. It follows then that a system of deep drainage and scientific irrigation is certain to be beneficial to farmers who cooperate in a well planned and managed wastewater system.

But it must be emphasized that a successful system must not apply more water than can be profitably utilized by agriculture. Toxic materials (i.e., heavy metals and organic materials from industrial discharge) must not be present in the effluent in quantities sufficiently high to cause toxicity to plants grown on the soil or to man or animals consuming the plants. The soil is a valuable resource that must be conserved.

Finally, this is a cooperative venture. Farmers gain benefit from utilization of water and drainage of land. But they also will contribute the invaluable knowledge gained through years of experience to produce the best possible soil management practices.

SECTION III - SOILS OF SOUTHEASTERN MICHIGAN

Description and location of soils

The quantity of water which can be conducted through the soil and the expected distribution of irrigation on the crops grown are closely related to soil properties. A basic premise is then that soil associations will form the building blocks for development of irrigation zones. Due to glaciation, Southeastern Michigan is laced with many soil series with widely varying properties. These occur in associations of varying complexity. For this reason soil associations were developed for the purposes of this study.

The soil association map of Southeastern Michigan was generalized from soil maps made as part of the National Cooperative Soil Survey program. The soils were grouped according to the dominant texture of the soil profile and the natural drainage conditions in which the soil was developed. These groups of soils are called soil management groups and they are designated systematically by number and letters (Table 1).

The mineral soils are given a number based on the dominant profile texture as follows: 0 = over 60 percent clay; 1 = 40 to 60 percent clay; 1.5 = clay loams; 2.5 = loams; 3 = sandy loams; 4 = loamy sands; and 5 = sands. Organic soils are indicated by a capital "M" for muck or peat. A fraction is used for soils with contrasting textures in the profile. For example, 3/2 represents soils which have 20 to 40 inches of sandy loam over loams to clay loams. Lower case letters following the numbers or capital letters indicate the natural drainage conditions in which the soil was formed:

a = light colored, well drained to moderately well drained; b = moderately dark colored, somewhat poorly drained; and c = dark colored, poorly drained.

Slope ranges were added to the soil management group for subdivision of the well drained management group. These subdivisions of the management groups are soil management units.* The slope gradient or lay of the land is expressed in the percent slope of the surface. The percent slope is equal to the number of feet rise or fall of the land surface for each 100 feet of horizontal distance. The slope range is indicated by the capital letters "A" for 0 to 6 percent slopes, and "C" for slopes greater than 6 percent.

The distribution of soil associations in Southeastern Michigan is shown in Figure 1. The soil associations are indicated by capital letters, beginning with "D" (to avoid repetition of letters used for slope classes.) They are described in Table 2 in alphabetical order. The description of each soil association is headed by the designation of the predominant soil management groups present and the predominant slope classes on which they occur.

Thus, Association D is nearly level (A slopes), somewhat poorly drained (b), and poorly drained (c) clay soils (0, 1). Some soils (0) contain more than 60% clay. In some areas up to 15% of the soils in the association have developed in sand or loamy sand over clay materials (4/1).

The placement of each soil series in Southeastern Michigan as used in the soil association descriptions and their soil management groups is as follows.

*These are very similar to the Land Capability Units used by the Soil Conservation Service, United States Department of Agriculture.

Soil Series	Soil Management Group	Soil Series	Soil Management Group
AuGres	5b	McBride	3a
Belding	3/2b	McGregor	3/5b
Belleville	4/2c	Metamora	3/2b
Blount	1.5b	Metea	4/2a
Boyer	4a	Miami	2.5a
Brady	4b	Montcalm	4a
Breckenridge	3/2c	Morley	1.5a
Brevort	4/2c	Nappanee	1b
Brookston	2.5c	Nester	1.5a
Capac	2.5b	Newaygo	3/5a
Carlisle	Mc	Oakville	5a
Celina	2.5a	Oshtemo	4a
Conover	2.5b	Owosso	3/2a
Corunna	3/2c	Palo	3/5b
Deford	4c	Parkhill	2.5c
Eastport	5a	Paulding	0b
Epoufette	4c	Pewamo	1.5c
Essexville	4/2c	Rifle	Mc
Fox	3/5a	Ronald	3/5c
Gilford	4c	Roscommon	5c
Gladwin	4b	Roselms	0b
Granby	5c	Rubicon	5a
Grayling	5a	Sebewa	3/5c
Greenwood	Mc	Selfridge	4/2b
Guelph	2.5a	Selkirk	1b
Hillsdale	3a	Sims	1.5c
Houghton	Mc	Spinks	4a
Hoytville	1c	St. Clair	1a
Iosco	4/2b	Tedrow	5b
Kawkawlin	1.5b	Thetford	4b
Kent	1a	Thomas	1.5c
Lapeer	3a	Toledo	1c
Londo	2.5b	Wainola	4b
Mancelona	4a	Wasepi	4b
Marlette	2.5a	Wisner	1.5c
Matherton	3/5b		

Table 1 -- Soil Management Group Identification Chart

Soil Management Group Numbers	Texture of the Soil Profile	Natural Drainage & Surface Color		
		Well Drained Light Colored a	Somewhat Poorly Drained Mod. Dark Colored b	Poorly Drained Dark Colored c
0	Clay (over 60%)	-	0b	0c
1	Clay to silty clay (40-60%)	1a	1b	1c
1.5	Clay loam	1.5a	1.5b	1.5c
2.5	Loam	2.5a	2.5b	2.5c
3	Sandy loam	3a	3b	3c
3/2	Sandy loam over loam or clay loam at 20"-40"	3/2a	3/2b	3/2c
3/5	Sandy loam over sand and gravel at 15"-40"	3/5a	3/5b	3/5c
4	Loamy sand	4a	4b	4c
4/1	Sands or loamy sands over clay to silty clay at 20"-40"	4/1a	4/1b	4/1c
4/2	Sand or loamy sand over loam or clay loam at 20"-40"	4/2a	4/2b	4/2c
5	Sand	5a	5b	5c
M	Muck or peat	-	-	Mc

Table 2--Description of Soil Associations

Soil Association	Dominant Soil Management Units	General Description
D	ObcA; lbcA	Nearly level, somewhat poorly drained and poorly drained clay soils. Some soils contain more than 60% clay. In some areas up to 15% of the soils in the association have developed from sand or loamy sand over the clay materials (4/1b and 4/1c soil management groups). In this soil association 95% of the soils have 0 to 6% slopes. Organic soils comprise 2% of the association. The principal soil series in this soil association are Toledo, Paulding, Nappanee, Hoytville and Roselms.
E	labCA	Undulating to hilly, well drained and somewhat poorly drained, clay and silty clay soils. In this soil association less than 40% of the soils have 0 to 6% slopes. Organic soils comprise 5% of the association. Wet, mineral soils in depressions and drainageways which are not drainable comprise 10% of the association. The principal soil series in this soil association are St. Clair and Nappanee.
F	lcbA; 1.5cbA	Nearly level, poorly drained and somewhat poorly drained clay and clay loam soils. In some areas up to 10% of the soils have developed from sand to loamy sand over the clay or clay loam material. In Genesee County about 20% of the soils have developed from loam materials (2.5cbA). In this soil association 95% of the soils have 0 to 6% slopes. Organic soils comprise 5% of the association. The principal soil series in this soil association are Hoytville, Nappanee, Pewamo, Sims, Wisner, Blount and Kawkawlin.
G	1.5abAC; labAC	Undulating to rolling, well drained and somewhat poorly drained clay loam and clay soils. In some areas up to 30% of the soils are deep sands or sand over clay loam or clay. In this soil association more than 55% of the soils have 0 to 6% slopes. Organic soils comprise 5% of the association. Wet, mineral soils in depressions and drainageways which are not drainable comprise 15% of the association. The principal soil series in this soil association are Morley, Blount, Nester, Kawkawlin, St. Clair, Nappanee, Kent and Selkirk.

Table 2--Description of Soil Associations (cont.)

Soil Association	Dominant Soil Management Units	General Description
H	1.5cbA; 2.5cbA; 4/2cbA; 3/2cbA	Level, poorly drained to somewhat poorly drained clay loam and loam soils. In the Saginaw Bay Area, 20 to 30% of soils are sandy to sandy loam over clay loam or loam. In this association 95% of the soils have 0 to 6% slopes. Organic soils comprise approximately 5% of the association. Wet, mineral soils in depressions or drainageways which are not drainable comprise less than 10% of the association. The principal soil series in this soil association are Pewamo, Sims, Blount, Kawkawlin, Brookston, Parkhill, Conover and Capac. The principal soil series which have developed from sand to sandy loam over clay loam or loam materials are Brevort, Iosco, Breckenridge and Belding.
I	2.5cbA; 1.5cbA; 3/2cbA; 4/2cbA	Nearly level, poorly drained loam and clay loam soils over dense compact till at variable depths. These soils occur mostly in Huron County. About 20% of the association has sandy loam or loamy sand over loam or clay loam with compact till at variable depths below the sandy upper story. In this soil association 95% of the soils have 0 to 6% slopes. Organic soils comprise 2% of the association. Wet mineral soils in drainageways which are not drainable comprise 2% of this association. The principal soil series in this soil association have not been correlated at this time.
J	1.5cbA; 3/2cbA; 4/2cbA	Nearly level, poorly drained and somewhat poorly drained clay loam and sandy loam or loamy sand over clay loam soils which are limy at the surface. In this soil association 95% of the soils have 0 to 6% slopes. Organic soils comprise less than 5% of the association. Wet, mineral soils in drainageways and depressions which are not drainable comprise less than 10% of the association. The principal soil series in this soil association are Wisner, Thomas, Kawkawlin, Essexville, Breckenridge, Belding, Brevort, and Iosco.
K	2.5aCA; 2.5abA; 1.5aCA;	Rolling to level, well drained and somewhat poorly drained loam and clay loam soils. Up to 35% of the soils have developed from sandy loam, loamy sand, sand, or sand or loamy sand over loam or clay loam. In this soil association approximately 65% of the soils have 0 to 6% slopes. Organic soils comprise less than 10% of the association. Wet, mineral soils in drainageways and depressions which are not drainable comprise 15% of the association. In St. Clair, Sanilac, Huron and Tuscola Counties 60% of the soils have 0 to 6% slopes. In these four counties

Table 2--Description of Soil Associations (cont.)

Soil Association	Dominant Soil Management Units	General Description
		organic soils and wet, mineral soils in drainageways and depressions comprise approximately 2 and 20% of the association, respectively. The principal soil series in this soil association are Miami, Celina, Marlette, Guelph, Conover, Capac, Londo, Morley, Nester, Owosso and Iosco.
L	2.5bcA; 1.5bcA; 4/2bcA	Nearly level, somewhat poorly drained and poorly drained loam and clay loam soils. Up to 25% of the soils have developed from sand to sandy loam over loam or clay loam or from loamy sand. In this association 80% of the soils have 0 to 6% slopes. Organic soils comprise 15% of the association. In Sanilac County up to 30% of the soils have developed from organic materials. Wet, mineral soils in drainageways and depressions which are not drainable comprise less than 15% of the association. The principal soil series in this soil association are Conover, Capac, Brookston, Parkhill, Blount, Kawkawlin, Pewamo, Sims, Selfridge and Brevort.
Mn	3/2bcA; 4/2bcA; 1.5bcA; 2.5bcA	Nearly level, somewhat poorly drained and poorly drained sandy loam or loamy sand over loam to clay loam, clay loam and loam soils. The sandy loam or loamy sand over clay loam or loam soils comprise 50 to 80% of this association. The part of this soil association located in the northern part of the area have 95% of the soils with less than 6% slopes. Organic soils comprise 5% of the association. Wet, mineral soils in drainageways and depressions which are not drainable comprise 10% of the association. The principal soil series in the northern part of the soil association are Belding, Breckenridge, Iosco, Brevort, Kawkawlin, Sims, Capac and Parkhill.
Ms	3/2bcA; 4/2bcA; 1.5bcA; 2.5bcA	Nearly level, somewhat poorly drained and poorly drained sandy loam or loamy sand over loam to clay loam, clay loam and loam soils. The sandy loam or loamy sand over clay loam or loam soils comprise 50 to 80% of this association. The part of this soil association located in the southern part of the area have 95% of the soils with less than 6% slopes. Organic soils comprise 2% of the association. Wet, mineral soils in drainageways and depressions which are not drainable comprise 5% of the association. The principal soil series in this part of the soil association are Metamora, Corunna, Selfridge, Belleville, Blount, Pewamo, Conover, and Brookston.

Table 2--Description of Soil Associations (cont.)

Soil Association	Dominant Soil Management Units	General Description
N	3aAC; 4aA	Undulating to rolling, well drained sandy loam soils. Soils developed in loamy sand or sandy loam over sand and gravel comprise 20 to 30% of this soil association. About 10% of the soils have developed from loam materials. About 65% of the soils have 0 to 6% slopes. Organic soils comprise 15% of the association. Wet, mineral soils in drainageways and depressions which are not drainable comprise 15% of the association. About 2% of the soils are shallow to bedrock. The principal soil series of this soil association are Hillsdale and Boyer. Significant amounts of Oshtemo, Fox, Spinks and Miami also occur in this association.
O	3aCA; 4aCA; 2.5aCA	Hilly to undulating, well drained sandy loam, loam and loamy sand soils. The sandy loam soils comprise 25 to 40% of this association. The association contains 25 to 50% of loamy sand soils and 10 to 25% of loam soils. In this association 50% of the soils have 0 to 6% slopes. Organic soils comprise 10% of this association. Wet, mineral soils in drainageways and depressions which are not drainable comprise 15% of the association. The principal soil series of this soil association are Lapeer, Hillsdale, McBride, Spinks, Boyer, Miami and Marlette.
P	3/5aA; 4aA	Nearly level, well drained sandy loam and loamy sand over sand and gravel soils. Twenty to fifty percent of the soils have sandy clay loam to clay loam subsoil. Up to 20% of the soils have developed from loam materials. Sand soils comprise 5 to 15% of this soil association. Up to 30% of the soils have developed from sandy loam materials. In this association 75% of the soils have 0 to 6% slopes. Organic soils comprise 10% of the association. Wet, mineral soils in drainageways or depressions which are not drainable comprise 15% of the association. The principal soil series of this soil association are Fox and Boyer. Significant amounts of Miami, Oakville and Hillsdale also occur in this association.

Table 2--Description of Soil Associations (cont.)

Soil Association	Dominant Soil Management Units	General Description
Q	3/5bcaA; 4bcaA	Nearly level, somewhat poorly drained, poorly drained and well drained sandy loam and loamy sand over sand and gravel soils. Areas of this soil association are long and narrow representing old glacial drainageways which may not be drainable. About 95% of the soils have 0 to 6% slopes. Organic soils comprise 2% of the association. The principal soil series in this soil association are Matherton, McGregor, Palo, Sebewa, Ronald, Fox, Newaygo Wasepi, Brady, Gladwin, Gilford, Epoufette, Boyer and Mancelona.
R	4aCA; 3/5aCA; 4/2aCA	Strongly sloping to undulating, well drained loamy sand and sandy loam over sand and gravel soils. Soils developed from loam and sandy loam materials comprise 10 to 20% of this soil association. Up to 25% of some areas of this association have loamy sand over loam soils. About 35% of the soils have 0 to 6% slopes. Organic soils comprise 20% of the association. Wet, mineral soils in drainageways and depressions which are not drainable comprise 15% of the association. The principal soil series in this soil association are Boyer, Spinks, Montcalm, Fox and Metea. Significant amounts of Miami, Hillsdale, McBride, Carlisle and Houghton occur in this association.
S	4abcA	Nearly level, well drained, somewhat poorly drained and poorly drained loamy sand over sand and gravel soils. In this soil association 95% of the soils have 0 to 6% slopes. Organic soils comprise 2% of this association. Wet, mineral soils in drainageways which are not drainable comprise 2% of the association. The principal soil series in this soil association are Boyer, Wasepi, and Gilford.
T	4bcA; 5aA	Level, somewhat poorly drained and poorly drained loamy sand soils with some well drained sand soils on ridges. This soil association includes the long narrow areas along Lake Huron and Saginaw Bay which are not drainable. Bedrock is near the surface on the east and north sides of Huron County. About 90% of the soils have 0 to 6% slopes. Organic soils comprise 5% of this association. The principal soil series in this soil association are Wainola, Deford, Eastport and new shallow to bedrock series in Huron County which have not been correlated.

Table 2--Description of Soil Associations (cont.)

Soil Association	Dominant Soil Management Units	General Description
U	5abcA; 4abcA	Nearly level to undulating, well drained, somewhat poorly drained and poorly drained sand and loamy sand soils. About 25% of the soils in this soil association located in St. Clair County have developed from clay. Up to 20% of the soils in this association have developed from sand or loamy sand over loam to clay loam materials. In this association 95% of the soils have 0 to 6% slopes. Organic soils comprise 2% of the association. Wet, mineral soils in drainageways which are not drainable comprise 10% of the association. The principal soil series in this soil association are Oakville, Tedrow, Granby, Spinks, Thetford, Ottawa and Selfridge.
V	5abcA	Nearly level to undulating, well drained, somewhat poorly drained and poorly drained sand soils. These soils contain spodic horizons which are subsoil accumulations of humus, iron and aluminum. About 20% of the soils have developed from sand over loam to clay materials. Up to 20% of the soils have developed from clay loam or clay materials. In this association 85% of the soils have 0 to 6% slopes. Organic soils comprise 15% of the association. Wet, mineral soils in depressions and drainageways which are not drainable comprise 10% of the association. The principal soil series in this soil association are Rubicon, Grayling, Au Gres, Roscommon and Iosco.
W	5bcA	Nearly level, somewhat poorly drained and poorly drained sand soils. The somewhat poorly drained soils have spodic horizons. Soils developed in loamy sand over clay loam or clay comprise up to 15% of the association. Well drained sandy soils occur on ridges. About 95% of the soils have 0 to 6% slopes. Organic soils comprise 15% of the association. Wet, mineral soils in depressions and drainageways which are not drainable comprise 10% of the association. The principal soil series in this soil association are Au Gres and Roscommon.
X	Mc	Level, poorly drained organic soils. Up to 25% of the soils in some areas of this association are mineral soils which are located between the large organic soil areas. Some organic soils are underlain with mineral soils at 16 to 51 inches. In this association 98% of the soils have 0 to 6% slopes. The principal soil series are Carlisle, Greenwood, Houghton and Rifle.

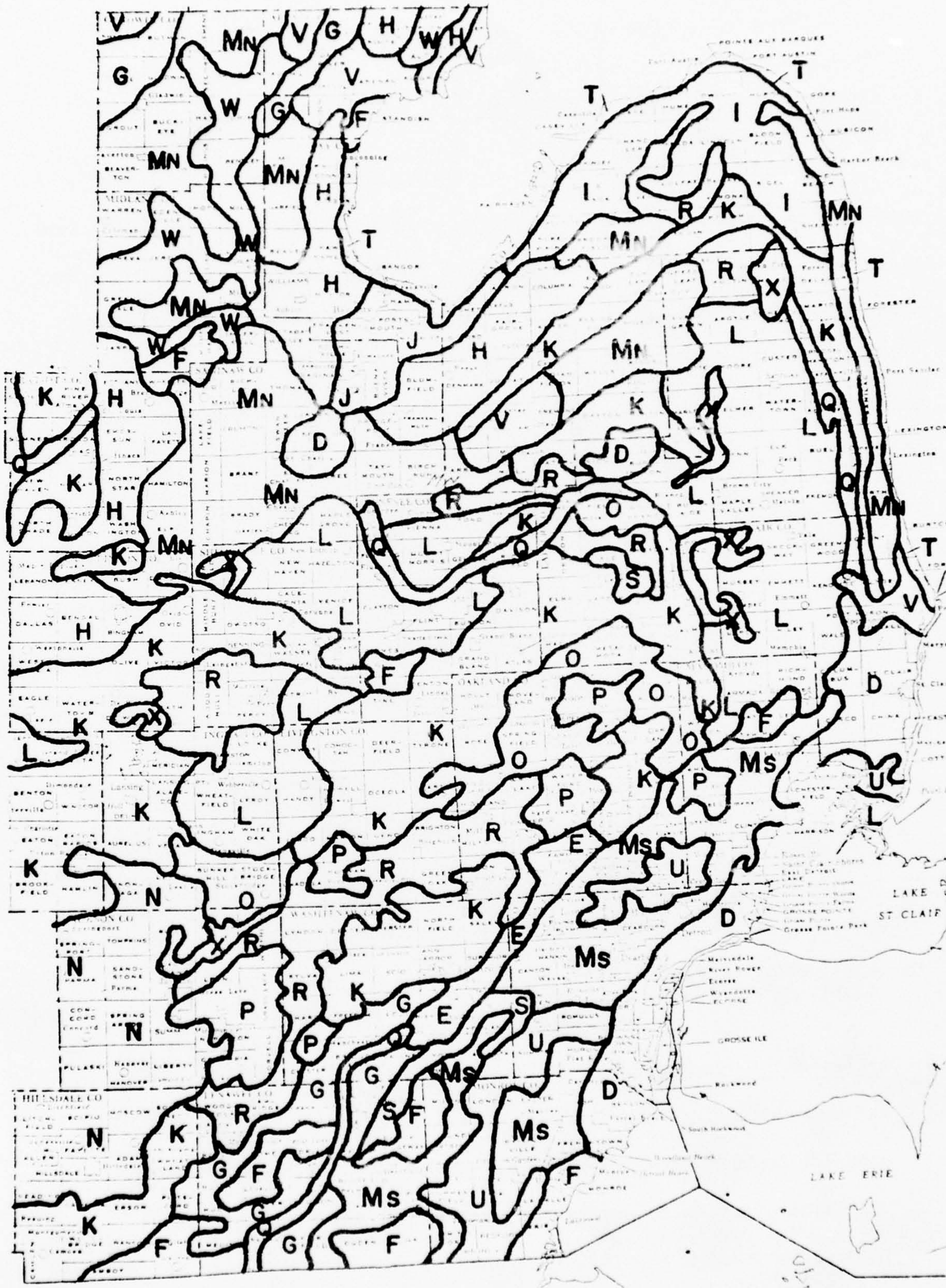


Figure 1
Major Soil Associations in Southeastern Michigan

SECTION IV - LAND USE AND CROPS IN EASTERN MICHIGAN

1. Description of existing conditions and projections for 1985 without irrigation.

Information was assembled from several sources and was evaluated with regard to potential utility in assessing base line data (existing conditions) and future impact (1985) with and without land disposal of wastewater being superimposed upon the system. The documents found to be most useful were CONSERVATION NEEDS INVENTORY (CNI) (1967), U. S. CENSUS (1969), MICHIGAN AGRICULTURAL STATISTICS (1970), MICHIGAN STATE UNIVERSITY AGRICULTURAL PROJECTIONS FOR 1985, and various miscellaneous sources.

An effort was made to identify and broadly define land units ranging from that which was in actual crop production acreage in 1969 to an estimate of the total acreage which could be utilized in a land application system.

The most broadly based definitions a, b, c and d below give the outermost limits of agricultural land which could be brought into production for a wastewater utilization project. In fact, the figures are just reference points since no allowances are made for recreational lands, land with developments but covering less than 10 acres, and numerous other improved areas. These definitions refer mainly to CNI data in Table 3 where land acreages and percentages of each county are divided into agricultural, forested, urban, and other lands.

Definitions

a. Agriculture: Includes (a) land currently tilled including field crops, fallow cropland, rotation hay and pasture, hay land (land permanently used for forage), temporarily idle cropland, orchards, vineyards and bush fruit, and open land formerly cropped. Also includes grasses, legumes or small grains grown on cropland but not harvested or pastured; all open acreage diverted from other crops under Federal programs,

Table 3--Land Use Patterns for Counties in Southeastern Michigan Adapted from Conservation Needs Inventory, 1968

County	Agriculture Acres (thousands)	%	Forestry Acres (thousands)	%	Urban Acres (thousands)	%	Other Acres (thousands)	%	County Land Area Acres (thousands)
Arenac	114.0	48.5	106.3	45.2	10.7	4.6	4.0	1.7	235
Bay	200.6	70.1	48.3	17.2	19.3	6.8	18.0	6.3	286
Clinton	279.3	76.3	45.0	12.3	20.7	5.6	18.0	4.9	366
Eaton	284.0	77.7	50.2	13.7	21.8	5.6	9.4	2.6	365
Genesee	175.3	42.7	52.0	12.7	131.4	32.0	52.1	12.7	411
Gladwin	113.1	35.1	188.8	58.6	14.5	4.5	5.7	1.8	322
Gratiot	209.9	80.4	50.8	14.0	19.4	5.3	.8	.3	362
Hillsdale	288.5	75.1	64.8	16.9	19.2	5.0	11.7	3.0	384
Huron	433.3	82.7	62.7	12.0	27.8	5.3	.3	.1	524
Ingham	246.5	68.9	53.0	14.8	44.6	12.5	13.6	3.8	358
Jackson	285.8	63.9	96.2	21.5	47.2	10.6	17.6	3.9	447
Lapeer	307.8	73.1	83.8	19.9	17.6	4.2	11.6	2.8	421
Lenawee	377.6	78.4	64.8	13.4	34.8	7.2	4.6	1.0	482
Livingston	237.7	64.9	94.2	25.7	27.1	7.4	7.1	1.9	366
Macomb	147.4	48.0	41.4	13.5	113.0	36.8	5.5	1.8	307

Table 3 (Continued)--Land Use Patterns for Counties in Southeastern Michigan Adapted from Conservation Needs Inventory, 1968

County	Agriculture Acres (thousands)	%	Forestry Acres (thousands)	%	Urban Acres (thousands)	%	Other Acres (thousands)	%	County Land Area Acres (thousdands)
Midland	119.4	37.0	180.7	56.1	24.6	7.4	8.1	2.5	332
Monroe	282	79.1	34.1	9.6	31.7	8.9	8.7	2.5	357
Oakland	185.5	34.1	145.3	26.7	163.8	30.1	49.9	9.2	545
Saginaw	340.6	65.4	97.5	18.7	64.7	12.4	17.9	3.4	521
Sanilac	510.8	83.1	70.4	11.4	26.1	4.2	7.7	1.3	615
Shiawassee	282.3	81.7	37.6	10.9	21.8	6.3	3.7	1.1	345
St. Clair	359.7	76.6	74.5	15.9	27.4	5.8	8.0	1.7	470
Tuscola	374.7	71.8	98.9	19.0	30.9	5.9	17.1	3.3	522
Washtenaw	316.8	69.7	83.5	18.4	48.3	10.6	6.1	1.4	455
Wayne	58.6	15.1	35.4	9.2	287.1	74.7	6.0	1.6	387

except that in summer fallow; other such land not under Federal programs; (b) Land in grass or other long term forage growth used primarily for grazing. Lands producing forage plants, principally introduced species, for animal consumption. In addition to regulating the intensity of grazing, management practices would usually include one or more recurring cultural treatments such as reseeding, renovation, reestablishment, mowing, liming, or fertilization. Pastures may be on drained or irrigated lands. The land may contain shade or timber trees if the canopy is less than 10%, but the principal plant cover must be such as to identify its use as permanent grazing land; (c) Other land considered a part of the farm, including farmsteads, farm roads, feed lots, ditch banks, fence and hedge rows, and the like.

b. Forest: Land that is at least 10% stocked by forest trees of any size that is capable of producing timber or other forest products or influencing a water regime. Land that formerly had at least 10% stocking by forest trees of any size and not currently developed for a non-forest use.

c. Urban: Areas that include: (a) cities, villages, and built-up areas of more than 10 acres; (b) industrial sites (except strip mines, borrow and gravel pits), railroad yards, cemeteries, airports, golf courses, shooting ranges, etc.; (c) institutional and public administrative sites and similar types of areas.

d. Other land: Difference between total land in county and sum of Forest, Urban and Agriculture.

Base line acreages of major crops (1969-70) and projected cropping patterns for 1985 within each of the counties in Southeastern Michigan are given in Section A. of Tables 4-a through 4-y. The 1969-70 data as taken from the U. S. Census 1969 and 1985 estimates were calculated by formula from the acres in each crop in 1969 and MSU projections of statewide crop acreage in

Table 4-a -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Arenac County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	9.0	13.9	8.3	15.0
Idle	14.3	22.0	14.3	25.9
Wheat	1.8	2.7	1.2	2.2
Other Small Grains	5.3	8.1	2.5	4.5
Hay	12.0	18.5	6.0	10.9
Dry Beans	10.0	15.4	9.0	16.3
Soybeans	1.6	2.4	1.8	3.3
Corn Grain	6.3	9.6	5.7	10.3
Corn Silage	2.7	4.2	4.3	7.8
Other	2.1	3.2	2.1	3.8
Total	65.1		55.2	

Other Agricultural Land (1969-70) = 26,500 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION							County
	F	G	H	M	V	W	X	Total
Acreage	15	43	43	7	85	21	21	235
% County	6	18	18	3	36	9	9	100
Agriculture								
Acreage	11.2	27.9	30.1	4.5	29.7	2.1	8.4	114.0
Percent	75	65	70	65	35	10	40	48.5
Forest								
Acreage	0.7	9.9	8.6	1.7	38.2	15.7	10.5	85.5
Percent	5	23	20	25	45	75	50	36.4
Urban								
Acreage	1.5	2.1	2.1	0	8.5	1.0	1.0	16.4
Percent	10	5	5	0	10	5	5	7.0
Other								
Acreage	1.5	3.0	2.1	0.7	8.5	2.1	1.0	19.0
Percent	10	7	5	10	10	10	5	8.1

*All acreage values tabulated in thousands of acres.

Table 4-b -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Bay County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	5.0	3.2	4.6	3.3
Idle	22.0	14.3	22.0	15.6
Wheat	10.3	6.6	7.0	5.0
Other Small Grains	3.9	2.5	1.9	1.3
Hay	6.3	4.0	3.1	2.2
Dry Beans	62.0	40.0	56.0	39.7
Soybeans	3.8	2.5	4.3	3.1
Corn Grain	8.0	5.2	7.2	5.1
Corn Silage	1.6	1.0	2.6	1.8
Other	32.2	20.7	32.2	22.9
Total	155.4		140.9	

Other Agricultural Land (1969-70) = 30,000 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION							County Total
	F	G	H	J	M	T	V	
Acreage	1	7	81	77	66	43	11	286
% of County	< 1	2	28	27	23	15	4	100
Agriculture								
Acreage	0.7	3.1	60.7	34.6	23.1	15.0	4.4	142
Percent	75	45	75	45	35	35	40	49.6
Forest								
Acreage	0.2	3.5	8.1	3.8	33.0	12.9	5.5	67.0
Percent	20	50	10	5	50	30	50	23.5
Urban								
Acreage	0.0	0.0	8.1	30.8	3.3	8.6	0.2	51.0
Percent	0.0	0.0	10	40	5	20	2	17.8
Other								
Acreage	< .1	.3	4.0	7.7	6.6	6.4	0.9	26.1
Percent	5	5	5	10	10	15	8	9.1

*All acreage values tabulated in thousands of acres.

Table 4-c -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Clinton County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1 9 8 5	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	21.8	9.6	20.1	10.5
Idle	58.0	25.6	58.0	30.2
Wheat	18.5	8.2	12.6	6.6
Other Small Grains	12.5	5.5	6.0	3.1
Hay	31.3	13.8	15.6	8.1
Dry Beans	14.0	6.2	12.6	6.6
Soybeans	20.9	9.2	23.6	12.3
Corn Grain	36.8	16.3	33.1	17.2
Corn Silage	11.4	5.0	10.3	5.4
Other	1.4	0.6	-	-
Total	225.8		191.9	

Other Agricultural Land (1969-70) = 61,000 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION						County
	H	K	L	M	R	X	Total
Acreage	138	149	2	33	33	11	364
% of County	38	41	< 1	9	9	3	99.5
Agriculture							
Acreage	96.6	104.3		26.4	21.4	6.6	255.3
Percent	70	70		80	65	60	70.2
Forest							
Acreage	13.8	14.9		1.6	6.6	1.1	38.0
Percent	10	10		5	20	10	10.5
Urban							
Acreage	13.8	14.9		3.3	1.6	2.2	35.8
Percent	10	10		10	5	20	9.8
Other							
Acreage	13.8	14.9		1.6	3.3	1.1	34.7
Percent	10	10		5	10	10	9.5

*All acreage values tabulated in thousands of acres.

Table 4-d -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Eaton County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	21.8	11.3	20.0	11.8
Idle	61.8	32.0	61.8	36.5
Wheat	17.9	9.3	12.2	7.2
Other Small Grains	9.2	4.8	4.4	2.6
Hay	23.9	12.4	11.9	7.0
Dry Beans	18.0	9.3	16.2	9.6
Soybeans	3.9	2.0	4.4	2.6
Corn Grain	29.0	15.0	26.1	15.4
Corn Silage	7.7	4.0	12.3	7.3
Other	0.0	0.0	-	-
Total	192.9		169.3	

Other Agricultural Land (169-70) = 66,900 acres.

B. Land Acreage Distribution Among Major Soil Associations
(Section B is for eastern half of Eaton County.)

	SOIL ASSOCIATION			1/2 County
	K	L	N	Total
Acreage	160	18	25	183
% of County	88	10	2	100
Agriculture				
Acreage	84.8	13.2	1.8	99.8
Percent	53	74	35	54.5
Forest				
Acreage	48	3.6	.6	52.0
Percent	30	20	10	28.4
Urban				
Acreage	16	0.6	2.2	18.8
Percent	10	3	45	10.3
Other				
Acreage	11.2	0.6	0.4	12.2
Percent	7	3	10	6.7

*All acreage values tabulated in thousands of acres.

Table 4-e -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Genesee County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	9.9	7.5	9.1	7.0
Idle	39.6	30.0	39.6	34.3
Wheat	121.0	9.2	8.2	7.1
Other Small Grains	8.1	6.1	3.9	3.4
Hay	17.9	13.5	8.9	7.7
Dry Beans	3.0	2.3	2.7	2.3
Soybeans	14.7	11.1	16.6	14.4
Corn Grain	19.8	15.0	17.8	15.4
Corn Silage	5.4	4.1	8.6	7.5
Other	1.6	1.2	-	-
Total	132.0		115.4	

Other Agricultural Land (1969-70) = 38,900 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION						County Total
	F	K	L	M	R	Q	
Acreage	24	131	172	24	16	45	412
% of County	6	32	42	6	4	11	100
Agriculture							
Acreage	16.8	45.8	60.2	9.6	4.0	13.5	149.9
Percent	70	35	35	40	25	30	36.4
Forest							
Acreage	4.8	19.6	17.2	6.0	8.0	6.8	62.4
Percent	20	15	10	25	50	15	15.2
Urban							
Acreage	1.2	45.8	68.8	4.8	1.6	18.0	140.2
Percent	5	35	40	20	10	40	34.0
Other							
Acreage	1.2	19.6	25.8	3.6	2.4	6.8	59.4
Percent	5	15	15	15	15	15	14.4

*All acreage values tabulated in thousands of acres.

Table 4-f -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Gladwin County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	16.8	30.0	15.5	34.5
Idle	10.6	18.8	10.6	23.6
Wheat	1.4	2.5	0.9	2.0
Other Small Grains	3.5	6.2	1.7	3.8
Hay	15.9	28.4	8.0	17.8
Dry Beans	1.2	2.1	1.1	2.4
Soybeans	0.2	0.4	0.2	0.4
Corn Grain	3.9	6.9	3.5	7.8
Corn Silage	2.1	3.7	3.4	7.6
Other	0.6	1.0	-	-
Total	56.3		44.9	

Other Agricultural Land (1969-70) = 35,200 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION				County
	G	M	V	W	Total
Acreage	58	138	23	103	322.0
% of County	18	43	7	32	100
Agriculture					
Acreage	36.5	20.7	4.6	5.1	67.0
Percent	63	15	20	5	20.8
Forest					
Acreage	17.4	98.0	17.7	92.7	225.8
Percent	30	71	77	90	70.1
Urban					
Acreage	1.2	5.5	0	0	6.7
Percent	2	4	0	0	2.1
Other					
Acreage	2.9	13.8	0.7	5.1	22.5
Percent	5	10	3	5	7.0

*All acreage values tabulated in thousands of acres.

Table 4-g -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Gratiot County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	11.0	4.4	10.1	4.4
Idle	45.5	18.3	45.5	20.2
Wheat	15.5	6.3	10.5	4.7
Other Small Grains	10.7	4.3	5.1	2.3
Hay	12.5	5.0	6.2	2.7
Dry Beans	78.0	31.4	70.2	31.1
Soybeans	21.5	8.7	24.3	10.8
Corn Grain	39.6	15.9	35.6	15.8
Corn Silage	6.5	2.6	10.4	4.6
Other	7.7	3.1	7.7	3.4
Total	248.5		225.6	

Other Agricultural Land (1969-70) = 53,900 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION					County
	F	H	K	M	Q	Total
Acreage	4	148	130	58	22	362
% of County	1	41	36	16	6	100
Agriculture						
Acreage	3	103.6	104	46.4	16.5	273.6
Percent	77	70	80	80	75	75.6
Forest						
Acreage	.6	14.8	13	5.8	3.3	37.5
Percent	15	10	10	10	15	10.4
Urban						
Acreage	.1	22.2	6.5	2.9	1.1	32.8
Percent	3	15	5	5	5	9.1
Other						
Acreage	.2	7.4	6.5	2.9	1.1	18.1
Percent	5	5	5	5	5	5

*All acreage values tabulated in thousands of acres.

Table 4-h -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Hillsdale County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	22.4	10.7	20.6	11.2
Idle	59.1	28.2	59.1	32.1
Wheat	14.9	7.1	10.1	5.5
Other Small Grains	11.8	5.7	5.7	3.1
Hay	26.6	12.7	13.3	7.2
Dry Beans	0.0	0.0	0.0	0.0
Soybeans	21.7	10.4	24.5	13.3
Corn Grain	43.6	20.8	39.2	21.3
Corn Silage	7.3	3.5	11.7	6.4
Other	1.9	.9	0	0.0
Total	209.0		184.2	

Other Agricultural Land (1969-70) = 69,900 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION					County
	F	G	K	N	R	Total
Acreage	46	12	157	168	1	384
% of County	12	3	41	44	< 1	100
Agriculture						
Acreage	33.1	10.0	103.6	122.6	.2	270
Percent	72	83	66	73	20	70.2
Forest						
Acreage	7.8	1.3	39.2	16.8	0	65.2
Percent	17	11	25	10	0	17.0
Urban						
Acreage	1.4	.1	6.3	11.8	0	19.5
Percent	3	1	3	7	0	5.1
Other						
Acreage	3.7	.6	7.8	16.8	.8	29.7
Percent	8	5	5	10	80	7.7

*All acreage values tabulated in thousands of acres.

Table 4-i -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Huron County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1 9 8 5	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	27.4	7.5	25.2	7.7
Idle	60.0	16.6	60.0	18.3
Wheat	31.6	8.7	21.5	6.6
Other Small Grains	23.0	6.4	11.0	3.4
Hay	43.7	12.1	21.8	6.6
Dry Beans	125.0	34.6	112.5	34.3
Soybeans	3.7	1.0	4.2	1.3
Corn Grain	44.5	12.3	40.1	12.2
Corn Silage	19.8	5.5	31.7	9.7
Other	0.0	0.0	0.0	0.0
Total	361.2		328.0	

Other Agricultural Land (1969-70) = 65,200 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION						County
	H	I	K	M	R	T	Total
Acreage	2	294	47	91	68	22	524
% of County	<1	56	9	17	13	4	100
Agriculture							
Acreage	1.8	235.2	25.8	59.1	51.0	8.8	381.8
Percent	90	80	55	65	75	40	72.9
Forest							
Acreage	.1	35.3	14.1	22.7	10.2	6.6	89.0
Percent	5	12	30	25	15	30	17.0
Urban							
Acreage	0	8.8	4.7	4.5	3.4	4.4	25.9
Percent	0	3	10	5	5	20	4.9
Other							
Acreage	.1	14.7	2.3	4.5	3.4	2.2	27.3
Percent	5	5	5	5	5	10	5.2

*All acreage values tabulated in thousands of acres.

Table 4-j -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Ingham County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (Thousands)	Fraction of Total %	Crop Acreage (Thousands)	Fraction of Total %
Pasture	16.5	10.1	15.2	11.5
Idle	45.1	27.7	45.1	34.1
Wheat	11.5	7.1	7.8	5.9
Other Small Grains	9.0	5.5	4.3	3.2
Hay	26.1	16.0	1.3	1.0
Dry Beans	1.5	0.9	1.3	1.0
Soybeans	5.0	3.1	5.6	4.2
Corn Grain	32.9	20.1	29.6	22.3
Corn Silage	11.4	7.0	18.2	13.7
Other	4.1	2.5	4.1	3.1
Total	162.7		132.5	

Other Agricultural Land (1969-70) = 67,900 Acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION						County Total
	K	L	N	O	R	X	
Acreage	111	111	47	65	21	2	357
% of County	31	31	13	18	6	<1	100
Agriculture							
Acreage	55.5	81	30.5	32.5	7.3	.3	207.3
Percent	50	73	65	50	35	15	58.1
Forest							
Acreage	5.5	13	7	26	2.1	.1	54
Percent	5	12	15	40	10	5	15.1
Urban							
Acreage	38.8	6.7	4.7	3.2	8.4	1.3	63.2
Percent	35	6	10	5	40	65	17.2
Other							
Acreage	11.1	10	4.7	3.2	3.1	.3	32.5
Percent	10	9	10	5	15	15	9.6

*All acreage values tabulated in thousands of acres.

Table 4-k -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Jackson County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	25.6	14.6	23.6	15.8
Idle	48.9	27.9	48.9	32.8
Wheat	10.0	5.7	6.8	4.6
Other Small Grains	10.3	5.9	4.9	3.3
Hay	34.6	19.8	16.6	11.1
Dry Beans	0.0	0.0	0.0	0.0
Soybeans	1.4	0.8	1.6	1.1
Corn Grain	31.4	17.9	28.3	19.0
Corn Silage	9.2	5.3	14.7	9.9
Other	3.7	2.1	3.7	2.5
Total	175.0		149.1	

Other Agricultural Land (1969-70) = 83,000 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION						County
	K	N	O	P	R	X	Total
Acreage	4	261	13	111	22	35	446
% of County	< 1	59	3	25	5	8	100
Agriculture							
Acreage	1.8	117.4	6.5	38.8	5.5	14.0	184.1
Percent	45	45	50	35	25	40	41.3
Forest							
Acreage	1	57.4	.6	27.7	2.2	3.5	92.5
Percent	25	22	5	25	10	10	20.7
Urban							
Acreage	.2	26.1	1.3	27.7	11	5.2	71.6
Percent	5	10	10	25	50	15	16.1
Other							
Acreage	1	60	4.5	16.6	3.3	12.2	97.8
Percent	25	23	35	15	15	35	21.9

*All acreage values tabulated in thousands of acres.

Table 4-1 -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Lapeer County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	23.1	12.8	21.3	14.0
Idle	46.1	25.6	46.1	30.3
Wheat	10.3	5.7	7.0	4.6
Other Small Grains	11.3	6.3	5.4	3.5
Hay	40.8	22.6	20.4	13.4
Dry Beans	6.9	3.8	6.2	4.1
Soybeans	.5	.3	.5	.3
Corn Grain	25.2	13.9	22.7	14.9
Corn Silage	10.6	5.9	17.0	11.2
Other	5.6	3.1	5.6	3.7
Total	180.0		152.2	

Other Agricultural Land (1969-70) = 65,900 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION								County
	D	K	L	O	R	Q	S	X	Total
Acreage	22	101	93	80	59	22	22	22	421
% of County	5	24	22	19	14	5	5	5	100
Agriculture									
Acreage	12.1	40.4	55.8	36	20.6	11	12.1	12.1	200.1
Percent	55	40	60	45	35	50	55	55	47.5
Forest									
Acreage	4.4	25.2	18.6	24.0	29.5	4.4	2.2	2.2	110.5
Percent	20	25	20	30	50	20	10	10	26.3
Urban									
Acreage	1.1	20.2	4.6	8	2.9	3.3	4.4	4.4	49
Percent	5	20	5	10	5	15	20	20	11.6
Other									
Acreage	4.4	15.1	13.9	12	5.9	3.3	3.3	3.3	61.3
Percent	20	15	15	15	10	15	15	15	14.6

*All acreage values tabulated in thousands of acres.

Table 4-m -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Lenawee County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	12.3	3.7	11.3	3.3
Idle	81.9	24.4	81.9	23.7
Wheat	31.3	9.4	21.3	6.2
Other Small Grains	15.5	4.6	7.4	2.1
Hay	21.8	6.5	10.9	3.1
Dry Beans	0.0	0.0	0.0	0.0
Soybeans	78.3	23.3	88.5	25.6
Corn Grain	77.0	23.0	69.3	20.0
Corn Silage	12.7	3.8	20.3	5.9
Other	35.2	10.5	35.2	10.2
Total	335.0		346.1	

Other Agricultural Land (1969-70) = 68,600 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION								County
	F	G	K	M	P	Q	R	S	Total
Acreage	125	173	10	67	1	29	58	19	482
% of County	26	36	2	14	< 1	6	12	4	100
Agriculture									
Acreage	106.2	112.4	7	56.9	.5	17.4	26.1	15.2	341.8
Percent	85	65	70	85	50	60	45	80	70.9
Forest									
Acreage	3.7	25.9	1.5	3.3	.1	1.4	8.7	1.9	46.7
Percent	3	15	15	5	10	5	15	10	9.7
Urban									
Acreage	8.7	25.9	1	3.3	.1	7.2	11.6	.9	58.9
Percent	7	15	10	5	10	25	20	5	12.2
Other									
Acreage	6.2	8.6	.5	3.3	.3	2.9	11.6	.9	34.5
Percent	5	5	5	5	30	10	20	5	7.2

*All acreage values tabulated in thousands of acres.

Table 4-n -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Livingston County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	16.5	13.7	15.2	14.9
Idle	31.5	26.2	31.5	30.8
Wheat	6.4	5.4	4.4	4.3
Other Small Grains	5.7	4.7	2.7	2.6
Hay	29.2	24.3	14.6	14.3
Dry Beans	0.0	0.0	0.0	0.0
Soybeans	0.7	0.6	0.8	0.8
Corn Grain	19.4	16.2	17.5	17.1
Corn Silage	8.1	6.7	13.0	12.7
Other	2.6	2.2	2.6	2.5
Total	119.8		102.3	

Other Agricultural Land (1969-70) = 54,000 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION						County
	K	L	O	P	Q	R	Total
Acreage	161	70	11	33	1	91	367
% of County	44	19	3	9	<1	25	100
Agriculture							
Acreage	96.6	49.0	8.2	18.1	.8	18.2	191
Percent	60	70	75	55	80	20	52.0
Forest							
Acreage	32.2	10.5	1.6	11.5	.1	31.8	87.9
Percent	20	15	15	35	15	35	24.0
Urban							
Acreage	16.1	3.5	.7	1.6	.1	18.2	40.3
Percent	10	5	7	5	5	20	11.0
Other							
Acreage	16.1	7	.3	1.6	0	22.7	47.8
Percent	10	10	3	5	0	25	13.0

*All acreage values tabulated in thousands of acres.

Table 4-o -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Macomb County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	6.9	9.0	6.3	9.2
Idle	23.1	30.0	23.1	33.8
Wheat	4.8	6.3	3.3	4.8
Other Small Grains	4.5	5.8	2.2	3.2
Hay	12.3	16.0	6.1	9.0
Dry Beans	1.7	2.2	1.5	2.2
Soybeans	3.0	3.4	3.4	5.0
Corn Grain	10.2	13.2	9.2	13.4
Corn Silage	3.8	4.9	6.1	9.0
Other	7.1	9.2	7.1	10.4
Total	77.4		68.3	

Other Agricultural Land (1969-70) = 19,900 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION								County
	D	F	K	L	M	O	P	U	Total
Acreage	18.5	24	24	59	46.4	12	18	12	201.9
% of County	6	8	8	19.6	15.2	4	6	4	66.8
Agriculture									
Acreage	7.4	16.8	9.6	38.3	32.5	4.2	4.5		113.3
Percent	40	70	40	65	70	35	25		56.1
Forest									
Acreage	3.7	2.4	6	5.9	4.6	3.6	4.5		30.7
Percent	20	10	25	10	10	30	25		15.2
Urban									
Acreage	3.7	3.6	2.4	11.8	7	1.2	7.2	12	36.9
Percent	20	15	10	20	15	10	40	100	18.3
Other									
Acreage	3.7	1.2	6	2.9	2.3	3	1.8		20.9
Percent	20	5	25	5	5	25	10		10.4

*All acreage values tabulated in thousands of acres.

**Maps were available for approximately 66.8% of this county. The available area was mainly agricultural, the unavailable area being residential.

Table 4-p -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Midland County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	5.5	7.6	5.1	8.0
Idle	15.6	21.5	15.6	24.6
Wheat	2.8	3.9	1.9	3.0
Other Small Grains	2.8	3.9	1.3	2.0
Hay	6.3	8.8	3.1	4.9
Dry Beans	28.0	39.0	25.2	39.7
Soybeans	3.5	4.9	4.0	6.3
Corn Grain	8.6	11.9	7.7	12.1
Corn Silage	1.6	2.2	2.6	4.1
Other	0.0	0.0	0.0	0.0
Total	72.3		63.4	

Other Agricultural Land (1969-70) = 29,000 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION				County
	F	H	M	W	Total
Acreage	23	30	143	137	333
% of County	7	9	43	41	100
Agriculture					
Acreage	19.5	19.5	35.7	20.5	95.3
Percent	85	65	25	15	28.6
Forest					
Acreage	2.3	4.5	78.6	89.0	174.5
Percent	10	15	55	65	52.4
Urban					
Acreage	0	4.5	14.3	13.7	32.5
Percent	0	15	10	10	9.8
Other					
Acreage	1.1	1.5	14.3	13.7	30.6
Percent	5	5	10	10	9.2

*All acreage values tabulated in thousands of acres.

Table 4-q -- Base line data and projections for cropping patterns patterns without wastewater application and distribution of major soil associations in Monroe County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	4.0	1.8	3.7	1.7
Idle	54.8	24.8	54.8	25.8
Wheat	22.7	10.3	15.4	7.2
Other Small Grains	9.3	4.2	4.5	2.1
Hay	6.3	2.9	3.1	1.5
Dry Beans	0.0	0.0	0.0	0.0
Soybeans	70.2	31.8	79.3	37.3
Corn Grain	39.3	17.7	35.4	16.7
Corn Silage	3.5	1.6	5.6	2.6
Other	10.8	4.9	10.8	5.1
Total	221.4		212.6	

Other Agricultural Land (1969-70) = 32,900

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION				County
	D	F	M	U	Total
Acreage	61	54	132	111	358
% of County	17	15	37	31	100
Agriculture					
Acreage	37.8	14.6	85.8	55	193.2
Percent	62	27	65	50	54.0
Forest					
Acreage	1.8	1.6	19.8	10	33.2
Percent	3	3	15	9	9.3
Urban					
Acreage	14	27	13.2	15	69.2
Percent	23	50	10	13	19.3
Other					
Acreage	7.3	10.8	13.2	31	62.3
Percent	12	20	10	28	17.4

*All acreage values tabulated in thousands of acres.

Table 4-r -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Oakland County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	14.2	20.7	13.1	22.8
Idle	20.5	30.2	20.5	35.7
Wheat	3.5	5.4	2.4	4.2
Other Small Grains	2.9	4.3	1.4	2.4
Hay	14.5	21.4	7.2	12.5
Dry Beans	0.0	0.0	0.0	0.0
Soybeans	.3	.5	.4	.7
Corn Grain	7.9	11.6	7.1	12.4
Corn Silage	1.8	2.6	2.9	5.1
Other	2.4	3.5	2.4	4.2
Total	68.0		57.4	

Other Agricultural Land (1969-70) = 33,800 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION							County
	E	K	M	O	P	R	U	Total
Acreage	33	142	54	142	98	54	22	545
% of County	6	26	10	26	18	10	4	100
Agriculture								
Acreage	6.6	39.8	1.1	35.5	11.8	10.8	.4	105.9
Percent	20	28	2	25	12	20	2	19.4
Forest								
Acreage	3.3	22.7	1.6	49.7	22.5	13.5	.4	113.8
Percent	10	16	3	35	23	25	2	20.9
Urban								
Acreage	18.1	56.8	40.5	35.5	49	21.6	1.8	223.3
Percent	55	40	75	25	50	40	81	41.0
Other								
Acreage	4.9	22.7	10.8	21.3	14.7	8.1	3.3	85.9
Percent	15	16	20	15	15	15	15	15.4

*All acreage values tabulated in thousands of acres.

Table 4-s -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Saginaw County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	9.2	3.2	8.5	3.3
Idle	39.7	13.7	39.7	15.3
Wheat	25.2	8.8	17.1	6.6
Other Small Grains	13.4	4.7	6.4	2.5
Hay	16.6	5.8	8.3	3.2
Dry Beans	82.0	28.6	73.8	28.4
Soybeans	41.9	14.6	47.3	18.2
Corn Grain	28.7	10.0	25.8	9.9
Corn Silage	4.6	1.6	7.4	2.8
Other	25.8	9.0	25.8	9.9
Total	286.6		260.1	

Other Agricultural Land (1969-70) = 60,800 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION					County Total
	D	J	H	L	M	
Acreage	48	48	89	28	308	521
% of County	9	9	17	5	59	100
Agriculture						
Acreage	28.8	12	53.4	22.4	169	286
Percent	60	25	60	80	55	54.9
Forest						
Acreage	9.6	4.8	8.9	2.8	61.6	87.7
Percent	20	10	10	10	20	16.8
Urban						
Acreage	2.4	26.4	17.8	0	46.2	92.8
Percent	5	55	20	0	15	17.8
Other						
Acreage	7.2	4.8	8.9	2.8	30.8	54.5
Percent	15	10	10	10	10	10.5

*All acreage values tabulated in thousands of acres.

Table 4-t -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Sanilac County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1 9 8 5	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	50.2	12.9	46.2	14.2
Idle	75.7	19.5	75.7	23.3
Wheat	25.4	6.5	16.2	5.0
Other Small Grains	35.3	9.1	16.9	5.2
Hay	75.2	19.4	37.6	11.6
Dry Beans	50.0	12.9	45.0	13.9
Soybeans	4.3	1.1	4.9	1.5
Corn Grain	42.1	10.9	37.9	11.7
Corn Silage	27.6	7.0	44.2	13.6
Other	2.7	.7	0.0	0.0
Total	389.0		324.6	

Other Agricultural Land (1969-70) = 72,100 acres.

B. Land Acreage Distribution Among Major Soil Associations

	S O I L A S S O C I A T I O N								County Total
	I	K	L	M	R	Q	T	X	
Acreage	4	80	308	98	34	41	28	23	615
% of County	<1	13	50	16	6	7	4	4	100
Agriculture									
Acreage	4	64	231	73.5	23.8	36	16	18.4	466.8
Percent	100	80	75	75	70	88	57	80	75.9
Forest									
Acreage	0	8	46.2	14.7	6.8	2.5	4.2	2.3	84.8
Percent	0	10	15	15	20	6	15	10	13.8
Urban									
Acreage	0	4	15.4	4.9	1.7	1.6	5.0	1.1	32.8
Percent	0	5	5	5	5	4	18	5	5.3
Other									
Acreage	0	4	15.4	4.9	1.7	.6	2.8	1.1	30.5
Percent	0	5	5	5	5	1.5	10	5	5

*All acreage values tabulated in thousands of acres.

Table 4-u -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Shiawassee County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	12.9	6.2	11.9	6.6
Idle	52.2	25.1	52.2	29.0
Wheat	20.9	10.1	14.2	7.9
Other Small Grains	14.2	6.8	6.8	3.8
Hay	23.3	11.3	11.6	6.5
Dry Beans	21.0	10.1	18.9	10.5
Soybeans	37.6	18.1	42.5	23.6
Corn Grain	24.5	11.8	22.0	12.2
Corn Silage	7.1	3.4	11.3	6.3
Other	0.0	0.0	0.0	0.0
Total	206.6		179.8	

Other Agricultural Land (1969-70) = 48,400 acres

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION				County
	K	L	R	X	Total
Acreage	93	173	69	10	345
% of County	27	50	20	3	100
Agriculture					
Acreage	65.1	121.1	34.5	9	229.7
Percent	70	70	50	90	66.6
Forest					
Acreage	13.9	17.3	20.7	.2	52.2
Percent	15	10	30	2	15.1
Urban					
Acreage	9.3	17.2	6.9	.3	33.7
Percent	10	10	10	3	9.8
Other					
Acreage	4.6	17.3	6.9	.5	29.3
Percent	5	10	10	5	8.5

*All acreage values tabulated in thousands of acres.

Table 4-v -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in St. Clair County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	26.8	15.4	24.6	14.4
Idle	50.1	28.8	50.1	29.4
Wheat	10.8	6.2	7.3	4.3
Other Small Grains	9.8	5.6	4.7	2.8
Hay	33.9	19.4	16.9	9.9
Dry Beans	5.5	3.2	4.9	2.9
Soybeans	4.3	2.5	4.9	2.9
Corn Grain	17.3	9.9	15.5	9.1
Corn Silage	10.2	5.8	16.3	9.6
Other	25.1	14.4	25.1	14.7
Total	174.4		170.3	

Other Agricultural Land (1969-70) = 43,800 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION								County
	D	K	L	M	T	U	V	X	Total
Acreage	136	16	204	9	23	23	35	23	469
% of County	29	4	39	2	5	5	8	5	100
Agriculture									
Acreage	68	9.6	119.9	7.2	6.9	11.5	1.7	17.2	242.1
Percent	50	60	59	80	30	50	5	75	51.6
Forest									
Acreage	27.2	4.8	25	.7	6.9	6.9	3.5	2.3	77.3
Percent	20	30	12	8	30	30	10	10	16.5
Urban									
Acreage	27.2	0	38.6	.4	6.9	2.3	24.5	1.5	101.1
Percent	20	0	19	5	30	10	70	5	21.6
Other									
Acreage	13.6	1.6	20.4	.6	2.3	2.3	5.2	2.3	48.4
Percent	10	10	10	7	10	10	15	10	10.3

*All acreage values tabulated in thousands of acres.

Table 4-w -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Tuscola County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	18.8	6.3	17.3	7.4
Idle	41.4	13.8	41.4	17.7
Wheat	31.1	10.4	21.1	9.0
Other Small Grains	25.2	8.4	12.1	5.2
Hay	25.8	8.6	12.9	5.5
Dry Beans	98.0	32.8	88.2	37.8
Soybeans	3.9	12.9	4.4	1.9
Corn Grain	35.7	11.9	32.1	13.8
Corn Silage	6.8	2.3	4.1	1.8
Other	0.0	0.0	0.0	0.0
Total	298.8		233.4	

Other Agricultural Land (1969-70) = 60,100 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION									County Total
	D	H	I	J	K	M	R	T	V	
Acreage	5	135	2	37	109	145	21	10	57	521
% of County	1	26	<1	7	21	28	4	2	11	100
Agriculture										
Acreage	4	108	1.6	29.6	58.7	58	12.6	0	22.8	295.3
Percent	80	80	80	80	55	40	60	0	40	56.7
Forest										
Acreage	.25	6.7	.1	1.8	22.6	50.7	7.3	3	19.9	112.5
Percent	5	5	5	5	20	35	35	30	35	21.6
Urban										
Acreage	.25	6.7	.1	1.8	11.2	7.2	0	0	2.8	30.2
Percent	5	5	5	5	10	5	0	0	5	5.8
Other										
Acreage	.5	13.5	.2	3.7	16.6	29	1	7	11.4	82.9
Percent	10	10	10	10	15	20	5	70	20	15.9

*All acreage values tabulated in thousands of acres.

Table 4-x -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Washtenaw County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1985	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	24.1	12.2	22.2	12.8
Idle	46.7	23.7	46.7	26.7
Wheat	15.5	7.9	10.5	6.0
Other Small Grains	14.5	7.4	7.0	4.0
Hay	36.1	18.3	18.0	10.3
Dry Beans	0.0	0.0	0.0	0.0
Soybeans	11.4	5.8	12.9	7.4
Corn Grain	37.2	18.9	33.5	19.2
Corn Silage	7.4	3.7	20.0	11.4
Other	4.1	2.1	4.1	2.3
Total	197.0		174.9	

Other Agricultural Land (1969-70) = 63,300 acres.

B. Land Acreage Distribution Among Major Soil Associations

	SOIL ASSOCIATION									County
	E	G	K	M	P	Q	R	S	U	Total
Acreage	34	68	159	34	23	11	80	34	11	454
% of County	8	15	35	8	5	3	18	8	3	100
Agriculture										
Acreage	10.2	27.2	87.4	20.4	13.8	4.4	60	13.6	8.2	245.3
Percent	30	40	55	60	60	40	75	40	75	54
Forest										
Acreage	8.5	23.8	31.8	5.1	2.3	3.8	8	5.1	1.6	90.1
Percent	25	35	20	15	10	35	10	15	15	19.8
Urban										
Acreage	11.9	10.2	23.8	5.1	1.1	.5	4	11.9	.5	69.2
Percent	35	15	15	15	5	5	5	35	5	15.2
Other										
Acreage	3.4	6.8	15.9	3.4	5.7	2.2	8	3.4	.5	49.4
Percent	10	10	10	10	25	20	10	10	5	10.9

*All acreage values tabulated in thousands of acres.

Table 4-y -- Base line data and projections for cropping patterns without wastewater application and distribution of major soil associations in Wayne County*

A. Cropping Patterns for 1969-70 and Projections for 1985

	1969-70		1 9 8 5	
	Crop Acreage (thousands)	Fraction of Total %	Crop Acreage (thousands)	Fraction of Total %
Pasture	2.4	6.1	2.2	5.9
Idle	10.9	28.2	10.9	29.2
Wheat	2.2	5.6	1.5	4.0
Other Small Grains	1.3	3.2	.6	1.6
Hay	2.6	6.8	1.3	3.5
Dry Beans	0.0	0.0	0.0	0.0
Soybeans	11.5	29.6	13.0	34.9
Corn Grain	4.3	10.9	3.9	10.5
Corn Silage	.4	1.2	.6	1.6
Other	3.3	8.4	3.3	8.8
Total	38.9		37.3	

Other Agricultural Land (1969-70) = 10,500 acres.

B. Land Acreage Distribution Among Major Soil Associations

	S O I L	A S S O C I A T I O N							County
	D	E	K	M	R	S	T	U	Total
Acreage	89	8	1	194	8	12	35	39	386
% of County	23	2	<1	50	2	3	9	10	100
Agriculture									
Acreage	8.9	2.4	.7	9.7	3.2	3	0	11.7	39.6
Percent	10	30	75	5	40	25	0	30	10.2
Forest									
Acreage	8.9	2	.2	9.7	2	2.4	3.5	11.7	40.4
Percent	10	25	20	5	25	20	10	30	10.5
Urban									
Acreage	62.3	2.4	0	155.2	2	4.2	28	9.7	263.8
Percent	70	30	0	80	25	35	80	25	68.4
Other									
Acreage	8.9	1.2	.05	19.4	.8	2.4	3.5	5.8	42.1
Percent	10	15	5	10	10	20	10	15	10.9

*All acreage values tabulated in thousands of acres.

1985. For example, corn acreage for grain in Michigan by 1985 is expected to be 80% of that planted in 1969. Definitions e, f, g, h and i given below pertain to Section A. of Tables 4-a - 4-y.

e. Acres in Crops. Land from which any crops were harvested. Land from which hay (including wild hay) was cut, and land in berries and other small fruits, orchards, vineyards, nurseries and greenhouses. Land used for rotation pasture and all other land used for pasture or grazing that the operator considered could have been used for crops without additional improvement.

f. Pasture. Includes rotation pasture and all other land used for pasture or grazing that the operator considered could have been used for crops without additional improvement. Includes land planted to crops that were hogged off, pastured, or grazed before maturity but excludes land pastured before or after hay or other crops were harvested from it.

g. Idle. Includes cropland used for soil-improvement crops, crop failure, cultivated summer fallow, and idle cropland.

h. Other Cropland. Difference between acres in crops and the sum of individual crops.

i. Other Agricultural Land. Difference between total land in farms and acres in cropland. Total land in farms includes: Land on which agricultural operations were conducted at any time during the census year under the control of an individual management. Places of less than 10 acres were counted as farms if the sales of agricultural products for the year amounted, or normally would

amount, to at least $250. Places of 10 or more acres were counted as farms if the sales of agricultural products for this year amounted, or normally would amount, to at least $50.

No basis for idle land and other crop projections was available so those acreages were assumed to remain at the 1969 levels for 1985 projection calculations. It is significant that all crops are expected to decline in acreage except for corn, silage and soybeans. There will probably be significant deviations from these projections especially in those counties where soybean acreage may increase much more rapidly than the statewide average (Table 5). Generally, these counties will be in the southern part of the study area where the growing season is longer (Hillsdale, Lenawee, Monroe and Shiawassee) and especially in counties where urban encroachment is minimal. Other counties such as Clinton, Gratiot and Saginaw also have appreciable soybean acreages. The active and idle cropland will be the area most easily utilized for wastewater application, but a separate category of other agricultural land may be important depending upon management schemes and public health considerations. This category contains woodlands, including woodland pasture, and permanent pasture which is not wooded, as well as areas containing developments that cannot be irrigated. Parts of these areas have been considered unsuitable for irrigation for the purposes of this report, but the acreages are considerable (ranging from a low of about 20 to over 50 percent of the amount of acreage in cropland) and they are a part of active farm units. The comparative acreages are summarized by county in Table 6. Such areas could be brought into partial production or used as alternate irrigation sites while primary sites are unavailable due to agricultural operations. A summary of 1969-70 cropping patterns by county is given in Table 5.

Table 5 -- Summary of cropland acreage and cropping patterns for counties in Southeastern Michigan for 1969-70.*

	AREA IN COUNTY			AGRICULTURAL USE OF CROPLAND							
	Total	Cropland	Portion in Cropland	Pasture	Idle	Corn	Other Small Grains	Wheat	Hay	Dry Beans	Soybeans
	- - Acres - -		- - % - -	- - - Acres - - -							
Arenac	235	65	27.6	9.0	14.3	9.0	5.3	1.8	12.0	10.0	1.6
Bay	286	155	54.3	5.0	22.3	9.6	3.9	10.3	6.3	62.0	3.8
Clinton	366	226	61.7	21.7	58.0	48.2	12.5	18.6	31.3	14.0	20.9
Eaton	366	193	52.8	21.8	61.8	36.7	9.2	17.9	23.9	18.0	3.9
Genesee	411	132	32.1	9.9	39.6	25.2	8.1	12.1	17.9	3.0	14.7
Gladwin	322	56	17.4	16.8	10.7	6.0	3.5	1.4	15.9	1.2	0.2
Gratiot	362	248	68.7	11.0	45.5	46.1	10.7	15.5	12.5	78.0	21.5
Hillsdale	384	209	54.5	22.4	59.0	50.9	11.8	14.9	26.6	-	21.7
Huron	524	361	69.0	27.4	60.0	64.3	23.0	31.6	43.7	125.0	3.7
Ingham	358	163	45.5	16.5	45.0	44.3	9.0	11.5	26.1	1.5	5.0
Jackson	447	175	39.2	25.6	48.9	40.6	10.3	10.0	34.6	-	1.4
Lapeer	421	180	42.7	23.1	46.1	35.8	11.3	10.3	40.8	6.9	0.4
Lenawee	482	335	69.6	12.3	81.9	89.7	15.5	31.3	21.8	-	78.3
Livingston	366	120	32.8	16.5	31.5	27.5	5.7	6.4	29.2	-	0.7
Macomb	307	77	25.2	6.9	23.1	14.0	4.5	4.8	12.3	1.7	3.0
Midland	333	72	21.7	5.5	15.6	10.2	2.8	2.8	6.3	28.0	3.5
Monroe	357	221	62.1	4.0	54.8	42.8	9.3	22.7	6.3	-	70.2
Oakland	545	68	12.5	14.1	20.5	9.7	2.9	3.5	14.5	-	0.3
Saginaw	521	287	55.0	9.2	39.7	33.3	13.4	25.2	16.6	82.0	41.9
Sanilac	615	389	63.2	50.2	75.7	69.7	35.3	25.4	75.2	50.0	4.3
Shiawassee	345	207	60.0	12.9	52.2	31.6	14.2	20.9	23.3	21.0	37.5
St. Clair	470	174	37.2	26.8	50.1	27.5	9.8	10.8	33.9	5.5	4.3
Tuscola	522	299	57.3	18.8	41.4	42.5	25.1	31.1	25.8	98.0	3.9
Washtenaw	455	197	43.4	24.1	46.7	44.6	14.5	15.5	36.2	-	11.4
Wayne	387	39	10.1	2.4	10.9	4.7	1.3	2.2	2.6	-	11.5

* Data adapted from U. S. Census, 1969.
All acreage values are given as thousands of acres.

In order to estimate how much land area in each county could be used for wastewater application, major soil associations were delineated on the basis of soil characteristics which are explained in Section III of this report. Since no previous data has been reported on the basis of soil association, the following procedure was developed to estimate the amount of agricultural, forest, urban and other acreages within each soil association by county.

The most recent aerial photograph from each of 25 counties in Southeastern Michigan was analyzed in making this land utilization analysis. Map pieces comprising a county were taped together to reproduce an accurate representation of the entire county. The county was then identified on the soil association map (Figure 1) and checks were made to assure that the map pieces were accounted for and the county shape was in fact what the aerial photo indicated. The soil associations given in Figure 1 were then delineated on the aerial photo by placing a moist cotton string on the photo to represent the soil association boundaries shown in Figure 1. Small pieces of masking tape were used to fasten the string to the photo. A soil type was then identified on the photo and an estimate was made of the percentage of land in forest, urban, agriculture and other uses by visual observations on the aerial photographs.

Since the estimation of land usage was necessarily subjective, two consultants independently estimated each area. Estimates were then compared and if major disagreement was found the area was re-examined and followed by discussion and negotiation until the two participants agreed on a mutually acceptable value for each soil type. If two or more blocks of a soil type were found in a county, each was analyzed separately and then a weighted average, based on the area, was used for obtaining the needed four percentage values.

When all of the soil types were completed for a county, the percentages were multiplied by the respective areas of each soil type. These acreages were summed and each sum was divided by the total acres in the county. Special attention was given to the agricultural percentage. It was corrected for airports, racing courses, visible parks, etc. The corrections varied from 5 percent for Gratiot county to 22 percent for Jackson county.

Although most of the aerial photographs were recent, a few were as old as 15 years. Because of rapid urbanization in some areas questions remained about the reliability of these photos to the present day situation. The 1969-1970 census data was used as a bench mark for these land utilization estimates. Sufficient variation between the census data and our analysis was found in 10 of the 25 counties to warrant re-examination of the aerial photographs. With the exception of 1 or 2 counties no major changes were made as a result of the re-examination. The detailed estimates by soil association are given for each county in Section B of Tables 4-a through 4-y. After the specific breakdown of estimated acreage within each soil association, the agricultural acreage was summed to determine a total estimated agricultural land area for each county. These summary values were then compared with total land in farms and total cropland in a county (Table 6). Generally, the estimated acreage for agricultural land fell between the acreage of cropland and land in farms (Table 6). In some instances, estimated agricultural land area was larger than total land in farms. These data indicate large amounts of potential farmland that is not in an active farm unit (i.e., no production for economic return) in 1969-70. Nevertheless, the land area could be put into production under the proper circumstances and with economic incentive.

Several points need to be emphasized. The data in Table 3 contain the

most broadly defined categories of agricultural, forested, urban and other land. These data are based on land use patterns and do not differentiate farmland from recreation land or other groupings. Forested land may be on farmland, in recreational areas, in state and national forests or in other locations. Hence, the information is of little value except for gross land utilization parameters.

The information in Table 6 probably has the greatest use for planning purposes. A general assumption has been made that land in active farm units will be most readily available for wastewater utilization. The active farm area is given by land in farms. Of the land in farms, the cropland will be most available for water application. Hence, separate values were placed in Table 6 to reflect the amount of acreage of farmland occupied by woodland and other uses (such as houses, roadways, ditches, permanent pastures, etc. Therefore, special decisions must be made about whether or not woodland, permanent pasture and other areas can be used for wastewater application. Estimated acreage values used in subsequent calculations assumed that some figure larger than active cropland in 1969-70 could be used for agricultural operations. Some large differences occurred in estimates and hard data. Livingston County is a good example. Estimated agricultural land is higher than the total land in farms in the county. This apparent discrepancy is probably due to the large recreational areas in that county that could be used for agricultural operations, such as wastewater utilization, but are not presently counted as land in farms. Can recreational areas be used for wastewater application? If not, the calculations used to estimate potential wastewater utilization by Livingston County may be too high. In other counties such as Macomb, Monroe and St. Clair much land that could be used in wastewater application is tied up in land speculation and these holdings are not reflected in land in farms. Thus, the estimated agricultural

Table 6 -- Summary data on land availability in active farm units, from 1969 U. S. Census, as compared to estimates made from soil association maps and aerial photo mosaics.*

	Land In County	LAND IN FARMS				Ag. Fraction of County Land		Estimated Ag. Fraction of County Land from Aerial Mosaics**	
		Total	Woods	Other**	Crops	Farms	Crops	Acres	%
	Acres					%			
Arenac	235	91	18	8	65	38.9	27.6	113	48.0
Bay	286	185	16	14	155	64.6	54.3	142	49.6
Clinton	366	287	27	34	226	78.4	61.7	257	70.2
Eaton	366	260	31	36	193	71.0	52.7	218	59.6
Genesee	411	171	17	22	132	42.6	32.1	150	36.4
Gladwin	322	91	22	13	56	28.4	17.4	68	21.1
Gratiot	362	302	30	24	248	83.4	68.5	274	75.7
Hillsdale	384	279	33	37	209	72.7	54.4	270	70.3
Huron	524	426	33	32	361	81.3	68.9	382	72.9
Ingham	358	231	24	45	163	64.5	45.5	209	58.3
Jackson	447	258	28	55	175	57.7	39.1	184	41.2
Lapeer	421	246	30	36	180	58.4	42.8	200	47.5
Lenawee	482	404	31	37	335	83.8	69.5	340	70.5
Livingston	366	174	21	33	120	47.5	32.7	191	52.2
Macomb	307	97	9	11	77	31.6	25.1	113	36.8
Midland	333	101	19	10	72	30.3	21.6	97	29.1
Monroe	357	254	15	17	221	71.4	61.9	194	54.3
Oakland	545	102	14	20	68	18.7	12.4	107	19.6
Saginaw	521	348	36	26	287	66.8	55.1	285	41.5
Sanilac	615	461	34	38	389	75.0	63.2	467	75.9
Shiawassee	345	258	22	30	207	74.8	60.0	230	66.7
St. Clair	470	218	21	23	174	46.3	37.0	242	51.5
Tuscola	522	359	31	29	299	68.8	57.2	297	56.9
Washtenaw	455	260	26	37	197	57.1	43.1	245	53.8
Wayne	387	50	5	6	39	12.5	10.0	40	10.3

* All data except estimated agricultural land is adapted from U. S. Census, 1969. All acreage figures expressed are in thousands of acres.

** County summary of estimated land area that may be used for agricultural operations. Values are the sum of land use distribution acreages estimated from aerial photographs by soil association in each county (see text for method).

fraction exceeds the land in farms in those counties.

Table 6 summarizes the cropland acreage and cropping patterns for counties in Southeastern Michigan for 1969-70. Arenac, Gladwin, Macomb, Midland, Oakland and Wayne Counties contained less than 100,000 acres of active cropland due to forested areas and urban development. Bay, Eaton, Genesee, Ingham, Jackson, Lapeer, Livingston, St.Clair and Washtenaw contained 100,000 to 200,000 acres of cropland. Clinton, Gratiot. Hillsdale, Monroe, Saginaw, Shiawassee and Tuscola contained 200,000 to 300,000 acres of cropland. Huron, Lenawee and Sanilac contained more than 300,000 acres of cropland. Dry beans and soybeans are important crops in many of the counties with large cropland acreage. Hence, water application on these areas may have major impacts if crops grown shift away from beans.

2. Description of Projected Conditions with Irrigation in 1985.

To estimate the distribution that will evolve by 1985 if the Southeastern portion of Michigan is irrigated with the maximum quantity of water that can be applied to each soil association and still maintain maximum crop production, the following items were considered relevant:

1. Soil association
2. Location
3. Present and projected trends without irrigation
4. Projected crop needs by 1985

The major crops which are expected to evolve are corn, soybeans and dry beans. For the purposes of this report soybeans and dry beans are grouped together as a single category. But generally, it will be assumed that the dry bean production will predominate in the lake plain region (i.e., Saginaw, Sanilac, Midland, Huron and Tuscola counties) and soybeans will predominate in other counties of the Southeast region. Here it should be emphasized that this assumes that technology will be evolved that will allow for the application of waste effluent to dry edible beans. Although soybeans could be grown in the same region, it must be recognized that greater than 95 percent of the dry edible beans grown in the United States are produced in this region. It is unlikely that any system that upsets this would be compatible with Michigan agriculture. Also, sugar beets are very significant in a few counties in the Thumb of Michigan. We did not consider them in our projections because the total acreage is less than 100,000 acres, an insignificant amount in the total area. But, again, they are such an important crop economically that they would have to be included in any irrigation of the Thumb area. The category "small grains" has been used to include any small grain (such as wheat and oats) or miscellaneous crops. Hay-pasture is largely expected to be alfalfa-brome mixture but

this category could include other legumes or pasture grasses as well.

Since soil association is a predominating factor in the determination of the crop distribution that will evolve, Table 7 was prepared to give estimates of the crop distribution by soil association.

The data in Table 7 was used in combination with the number of useable acres of each soil association in each county to arrive at the number of acres of each crop that will evolve in each county with irrigation, and are given in Tables 21a through y.

Table 7 -- Projected Crop Distribution with Irrigation by 1985.

Soil Association	Corn	Beans	Small Grains	Hay Pasture	Trees
	%				
D, E, Q, T, & X	None				
F	60	20		20	
G	60	20		20	
H	35	40	10	15	
I	35	40	10	15	
J	35	40	10	15	
K	60	20	10	10	
L	35	35	10	20	
M north	25	50	20	5	
M south	40	40	20		
N	55	10	10	25	
O	60	20	10	10	
P	55	10	10	25	
R	75	10	10	5	
S	75	10	10	5	
U	40	40	10	10	
V & W					100

SECTION V - PROJECTED APPLICATION OF WASTEWATER IN SOUTHEASTERN MICHIGAN

1. Application Rates

There have been several recent discussions of the application rates at which wastewater may be applied to land (Technical Report No. 30, Institute of Water Research, MSU, 1972; CRREL, 1972). The infiltration rate (the rate at which water enters the soil surface) and the permeability/or hydraulic conductivity (the rate at which water passes through any subsurface horizon of the soil) are the parameters that are measured in the field or laboratory and are used for irrigation design, drainage design and to estimate the runoff characteristics of a soil. However, the use of this data directly for the design of wastewater treatment systems which would be compatible with the agricultural crop production is fraught with real difficulties. The problem is caused by the following:

1) Infiltration and permeability data used for irrigation design presupposes that the soil is initially dry and that only enough water is added to fill the water magazine.

2) Permeability data used for drainage design is used to remove excess water under calamity situations during which the crop may be suffering from excess water.

3) Agricultural soils are dynamic and under long periods of excessive wetness the permeability of the soil will decrease.

4) Agricultural soils can only recover their initial infiltration rates by cycles of dehydration and careful management.

5) Agricultural soils must be maintained in an aerated condition to produce acceptable crop yields.

6) Aerated soil conditions are necessary for the best treatment of both organic, inorganic and possible pathogenic materials in the wastewater.

For these reasons, it is not possible to design waste disposal systems using infiltration and saturated hydraulic conductivity data. Soils used in this way would be waterlogged, and the conductivities would reduce with time. They would be worthless for crop production and inefficient in waste treatment.

A successful wastewater system should be designed to be aerated in the root zone at all times. This requires the use of unsaturated hydraulic conductivity data in the least permeable soil horizon. As air enters the soil pores, the hydraulic conductivities drop very rapidly by one or even two orders of magnitude. Thus, systems that are considered conservative because of large safety factors applied to designs using saturated conductivity data could be complete failures in operation.

Unsaturated hydraulic conductivity data is very difficult to obtain for agricultural soils. Little of this data is available for natural soils. Actually, because of the dynamic nature of the soil structure there may be great change in the unsaturated conductivities in the field throughout the season. When these difficulties are coupled with the natural variability of the soil it becomes almost an unsolvable problem even if the data existed.

The only practical solution that can be given for the wastewater disposal problem today must come from experiences and observations of farm operations during long periods of wet weather and rainfall after supplemental irrigation. The best possible estimates of the yearly application were made by the MSU Soil Science Group and were used in the development of the irrigation treatment schedules for the Cropping Systems and Irrigation Schedules in V4 of this report.

These systems and schedules consider the necessity of periods of drying to get the soil dry enough for soil or crop manipulation. They also propose the wastewater applications for a period considering the normal rainfall in

the period. They also leave time for the soil to dry on the surface and undergo cycles of drainage and partial dehydration to insure the recovery of infiltration and permeability rates.

The recommended instantaneous rate of application for wastewater application on the various soil management groups would be as follows:

Soil Management Group	Rate - Inches/hour
1	0.05 - 0.1
1.5	0.1
2.5	0.25
3	0.35
3/5	0.35
4	0.5
5	1.0

No application should be over 1-1/2 or 2 inches and should include a drying period between irrigations and between irrigations and rainfalls of one inch or more. The drying is necessary to limit plant diseases and allow for drainage, the recovery of aerated conditions and the recovery of infiltration and permeability capacities. To insure the maintenance of infiltration rates the soil surface should be protected by a cover crop whenever possible. This has also been considered in the development of cropping systems in Section V4.

Because wind influences the distribution pattern and gives an aerosol effect, night irrigation when the winds are usually lowest should be considered.

No soil with a slope greater than 6% has been considered in this study because of the erosion hazard and difficulty of applying water and limiting runoff. This is further complicated by the fact that many soils with these slopes have been eroded so that the subsoil is exposed and this presents a condition of much lower infiltration than the uneroded soils.

A potential problem is the dispersing effect that sodium and potassium can have on the soil if they are in high enough concentrations in the waste-

water. This could cause a reduction in the infiltration rates and permabilities with time. The calculated SAR and predicted ESPs for the Detroit effluent profile was shown to be on the borderline (Technical Report No. 30 - Institute of Water Research, MSU, 1972). In the event the actual profile has a higher concentration of mono-valent cations, a problem could develop but might be corrected by reducing the amounts of sodium chloride used in street salting.

The subsoil in the 3/5 soils is very dense and has a low permeability. However, a deep mixing technique has been developed for these soils (Piper, 1967) that would be relatively inexpensive and could make it possible to treat these soils like Group 3 soils. It is proposed that these soils be deep disked with a giant disk to a depth greater than the depth of the dense subsoil. This manipulation which should cost about $50.00 per acre is assumed in Section V4.

2. Nutrient Balance

a. Effluent inputs and crop uptake.

In Table 8, mineral inputs have been calculated for the effluent profile in the second column. The 9.8 mg/l of "crop-available N" derives from the calculations of Table 9, where allowance is made for incomplete mineralization of N in resistant organics (1.05 mg/l) and for loss by denitrification of 4.18 mg N/l (30% of the seasonal mineral N increment). These calculations follow the rationale developed in Technical Report No. 30 (Institute of Water Research, MSU, 1972).

Crop compositions in Tables 10 and 12 were taken from several compilations published over the period 1941 to 1968. The selection of values for use in this study was somewhat arbitrary, but an attempt was made to weight them on the basis

of numbers of analyses reported. In general, this favored values closer to the means derived from the more recent summaries.

The selected means cannot be interpreted as "adequate" or "optimum." It is clear from the reported ranges that crop content can vary widely in the direction of deficiency, as well as in the direction of luxury consumption, even toxicity. A higher concentration due to luxury consumption will increase harvest removal of nutrients. However, this will not be true if the high concentration of one or more nutrients is associated with yield reductions due to deficiencies or toxic levels of others.

The crop compositions in Tables 10 and 12 were used to calculate harvest removals in Tables 11 and 13.

Cursory comparison of Tables 8 and 11 indicates that P supplied in effluent will exceed removal by most crops except at low irrigation rates. On the other hand, all crops except wheat (grain only) will remove more N than supplied in 45 inches of effluent; corn silage, alfalfa-brome and sugar beets will remove more K. Five tons of alfalfa-brome hay will remove the Ca supplied in 20 inches of effluent and the Mg in 35 inches.

To maintain the desired yield goals, it will be necessary to augment the effluent with N and/or K from fertilizer sources for several crops. Substantial quantities of K will be required to balance removals by corn silage, alfalfa-brome and sugar beets. This raises the possibility, on initially acid, coarse-textured soils, that unfavorable balances between K, Ca and Mg may develop. The use of dolomitic limestone for correcting pH in

such soils is indicated.

The quantities of fertilizer nutrients required to maintain desired yield levels cannot be determined by inspection of input-output balances. Procedures and criteria for monitoring and control of nutrient status in waste disposal systems can only be developed as operating systems become available for study. These will likely include routine soil tests (SSSA Special Publication No. 2, Part I, 1967; Mich. Ext. Bul. E-550, 1972), quick tissue tests (Mich. Spec. Bul. 353), and plant analysis (SSSA Spec. Publication No. 2, Part II, 1967).

Initial estimates of fertilizer needs in the study area can be based on soil tests of the plow layer and fertilizer recommendations formulated in Mich. Extension Bulletin E-550 (1972). Illustrative calculations are presented in Tables 20 and 21 of Section V4.

b. Nitrogen balance.

Soil tests used for P, K, Ca and Mg in the Michigan system permit prediction of nutrient requirements for a crop in advance and will also detect changes over a period of years due to depletion or cumulative carryover. Similarly reliable soil tests for N are not available. Tests for nitrate and ammonium are extremely sensitive. However, the mobility of nitrate and the susceptibility of both to rapid transformation calls for a great deal of judgment with regard to time and depth of sampling, handling of samples prior to analysis and interpretation of the results. The usefulness of the Kjeldahl N determination is limited by variations inherent in sampling, sample preparation and the analysis itself, and by seasonal fluctuations associated

with annual cycles of organic matter decomposition. Promising tests for "active" fractions of soil N are being developed but need extensive field calibration.

Tests for nitrate in drainage water and surface soils, and profile distributions of nitrate in soil at critical times of the year will certainly be necessary to assess efficiency of N utilization in waste disposal systems. Such information will provide the basis for adjusting past management practices.

However, until soil tests and criteria for estimating year-to-year carryover of available N are developed, judgments regarding quantities of fertilizer N to use on a given crop must be based initially on principles derived from experience with cropping systems of the past. Principles outlined on p. 8 of Mich. Ext. Bul. E-550 and guides for N fertilizer use in Tables 5, 6 and 7 of the same bulletin were used in the illustrative calculations of Tables 20 and 21.

The estimates in Tables 20 to 21 may be summarized as follows:

1) On soils which can receive 35 inches or more of wastewater annually, the effluent will supply essentially all of the nitrogen necessary for the desired yields of all crops except corn following a non-legume.

2) At lower annual rates of waste irrigation, increasing amounts of fertilizer N (up to 150 lb/a) will be required for corn. Small starter quantities may also be required for soybeans, wheat and sugar beets.

3) Judgment as to number and timing of irrigation inputs of N will be necessary to avoid lodging of wheat or impaired recovery of sugar from sugar beets.

4) If all crops are managed for maximum production and if vigorous winter cover crops are used, supplemental fertilizer nitrogen can be distributed seasonally by additions to irrigation water so that large accumulations of mobile nitrate need not occur at any time.

Table 8 -- Nutrient Inputs, by Acre-inches of Applied Effluent

Nutrient	mg/1	Acre-inches of Sewage Effluent							
		1[c]	15	20	25	30	35	40	45
		lb/acre							
N	9.8[a]	2.22	33	44	55	66	77	88	99
P	7.0[b]	1.59	24	32	40	48	56	64	72
K	7-10	1.93	29	39	48	58	68	77	87
Ca	1-40	4.53	68	91	113	136	159	181	204
Mg	1-10	1.13	17	23	28	34	40	46	51
Na	40-100	15.9	238	318	397	476	556	636	715
Fe	5.6[b]	1.27	19	25	32	38	44	51	57
Cu	.18[b]	.041	.6	.8	1.0	1.2	1.4	1.6	1.8
Ni	.41[b]	.093	1.4	1.9	2.3	2.8	3.3	3.7	4.2
Zn	.44[b]	.10	1.5	2.0	2.5	3.0	3.5	4.0	4.5
Pb	.01-.10	.01	.15	.2	.25	.3	.35	.4	.45
Hg	<.005	<.001	.015	.02	.025	.03	.035	.04	.045
B	.5-1.0	.17	2.55	3.4	4.25	5.1	5.95	6.8	7.65
Cl	40-100	15.9	239	318	398	478	556	637	717
SO_4	12-52	7.25	109	145	182	218	254	290	326

a - Crop-available N, after allowing for immobilization and denitrification, Table f.

b - Values for P, Fe, Cu, Ni and Zn were specified by the Army Corps of Engineers, Detroit District (personal communication). Other values are from Table 3-I, p. 36, CRREL, 1972.

c - Conversion factor: .2266 X mg/1 = lb/a/in. Where a range of concentrations are shown in Column 2, the median value is converted.

Table 9 -- Crop-available N in Effluent: Corrections for Incomplete Mineralization and for Denitrification

Component	Concentrations in Effluent			
	mg/l		lb/a/in	
A. Inputs				
COD (Total)	60		13.6	
BOD_5		20		4.5
Resistant organics ($COD-BOD_5$)		40		9.1
Total N	15		3.4	
Organic		1.5		.34
NH_4		6.9		1.56
NO_3		6.6		1.50
B. Conversions of Carbon in the Field:				
Loss of BOD_5 materials (80%)		(16)		
Loss of COD in resistant organics (10%)		(4)		
Residual COD in soil		40	9.1	
Residual organic carbon (COD X 12/32 X 0.7)[a]		10.5		2.4[b]
C. Fate of N in the field:				
Residual organic N (C/N = 10/1)		1.05	.24	
N mineralized (Input - Residual Org. N)		.45		
Input Mineral N ($NH_4 + NO_3$)		13.5		
Mineral N Increment (Input + Mineralized)		13.95		
Denitrification Loss (30%)		(4.18)		(.95)
Net Plant Available N		9.77	2.21	

a - Organic carbon = COD X 12/32 X 0.7
Note: Factor 0.7 allows for 30% reducing substances other than C in COD determination.

b - To convert carbon to organic matter, multiply by 1.728.

Table 10 -- Major and Secondary Nutrients in Crops.[a]

Crop	Nutrient	Percent of Harvest Weight: This Study	Beeson 1941 (1)	Morrison 1959 (2)	Am. Pot Inst. 1965 (3)	NRC 1968 (4)	Reported Ranges
Corn grain 15.5% moisture	N	1.46	-	1.40	1.61	1.38	1.12 - 1.91
	P	.26	.36	.26	.26	.26	.03 - .68
	K	.33	.34	.32	.35	.32	.19 - .78
	Ca	.03	.01	.03	-	.03	.00 - .09
	Mg	.12	.14	.10	-	.14	.07 - .76
	S	.12	.12	.12	-	.12	.03 - .25
Corn silage 75% moisture	N	.33	-	.33	.30	.33	.14 - .64
	P	.06	.05	.06	.06	.06	.02 - .14
	K	.30	.65	.28	.34	.29	.15 - .65
	Ca	.09	.12	.09	-	.08	.02 - .20
	Mg	.06	.06	.05	-	.06	.01 - .15
	S	.03	.07	.03	-	.03	.01 - .07
Alfalfa - brome hay 10% moisture	N	2.20	-	1.89	2.67	2.03	1.89 - 2.67
	P	.30	.24	.20	.31	.31	.13 - .46
	K	1.66	2.00	1.66	1.87	1.44	.50 - 3.86
	Ca	.90	1.81	.77	-	1.02	.53 - 3.74
	Mg	.37	.23	.21	-	.53	.15 - .96
	S	.21	.23	.21	-	.21	.18 - .27
Wheat grain 10% moisture	N	2.00	-	2.12	2.08	1.73	1.17 - 2.66
	P	.37	.36	.39	.42	.30	.07 - .50
	K	.39	.43	.42	.35	.40	.26 - .56
	Ca	.06	.04	.04	-	.09	.01 - .36
	Mg	.12	.15	.14	-	.10	.08 - .26
	S	.19	.16	.20	-	.17	.09 - .29

Table 10 (Continued) -- Major and Secondary Nutrients in Crops[a]

		Percent of Harvest Weight					
	Nutrient	This Study	Beeson 1941 (1)	Morrison 1959 (2)	Am. Pot. Inst. 1965 (3)	NRC 1968 (4)	Reported Ranges
Soybean seed 10% moisture	N	5.70	-	6.06	5.33	-	6.06 - 5.33
	P	.59	.70	.59	.58	-	.45 - .97
	K	1.72	1.65	1.50	1.94	-	.73 - 2.15
	Ca	.25	.22	.25	-	-	.17 - .27
	Mg	.28	.28	.28	-	-	.22 - .31
	S	.22	.22	.22	-	-	.09 - .40
Sugar beet roots 80% moisture	N	.208	-	-	.208	-	.208
	P	.036	.022	-	.036	-	.006 - .066
	K	.278	.128	-	.278	-	.074 - .278
	Ca	.044	.044	-	-	-	.022 - .070
	Mg	.032	.032	-	-	-	.022 - .046
	S	.014	.014	-	-	-	.006 - .026

a - Values from following sources, converted to common moisture basis and unit concentration:

(1) Beeson, K. C., 1941. The mineral composition of crops with particular reference to the soils in which they are grown. U.S.D.A. Misc. Pub'n No. 369.

(2) Morrison, F.B., 1959. Feeds and Feeding. The Morrison Pub. Co., Clinton, Iowa. Tables I and IV. (Reported values corrected to moisture contents in Column 1.)

(3) Romaine, J.D., 1965. Consider plant food content. Better Crops. May-June, 1965, Pp 1-8. American Potash Institute, Inc., Washington, D.C. (Calculated percentages, moisture content not known.)

(4) Miller, D.F., 1968. Composition of Cereal Grains and Forages. Publication 585. National Academy of Sciences, National Research Council, Washington, D.C. Tables I, II-A and III-C. (Values corrected to moisture contents in Column 1.)

Table 11 - Yield Goals and Removal of Major and Secondary Nutrients in Crops

Crop	Yield Goal	Nutrient	Removal in Harvested Crop
			lb/a
Corn grain	150 bu/a	N	125
15.5% moisture		P	22
		K	28
		Ca	3
		Mg	10
		S	10
Corn silage	25 T/a	N	165
75% moisture		P	30
		K	150
		Ca	45
		Mg	30
		S	15
Alfalfa-brome	5 T/a	N	220
10% moisture		P	30
		K	166
		Ca	90
		Mg	37
		S	21
Wheat, grain	60 bu/a	N	72
10% moisture		P	13
		K	14
		Ca	2
		Mg	4
		S	7
Soybeans	35 bu/a	N	120
10% moisture		P	12
		K	36
		Ca	5
		Mg	6
		S	5
Sugar beets	25 T/a	N	104
		P	18
		K	140
		Ca	22
		Mg	16
		S	7

Table 12 -- Micro-elements in Crops[a]

Crop	Nutrient	Unit	This Study	Beeson 1941	Morrison 1959	NRC 1968	Reported Ranges
Corn grain	Fe	ppm	50	57	44	55	25 - 380
15.5% moisture	Mn	"	10	11	4	4	.5 - 45
	Cu	"	5	7	2.5	3.4	.7 - 14
	Zn	"	15	17	-	10	10 - 17
	Co	"	.04	.009	-	.07	.006 - .2
	Na	%	.03	.04	.01	.01	0 - .1
	Cl	%	.03	.02	.04	.04	.004 - .06
Corn silage	Fe	ppm	80	-	66	110	22 - 330
75% moisture	Mn	"	15	-	18	12	1 - 22
	Cu	"	2	-	1.2	2.6	.6 - 14
	Zn	"	5	-	-	5	5
	Co	"	.02	-	-	.02	.02
	Na	%	.01	-	.01	.01	0 - .02
	Cl	%	.05	-	.05	.05	.02 - .14
Alfalfa hay	Fe	ppm	100	259	308	242	198 - 900
10% moisture	Mn	"	50	67	49	34	13 - 842
	Cu	"	15	8	11	16	3 - 14
	Zn	"	40	43	-	-	43
	Co	"	.1	-	-	.08	.04 - .11
	Na	%	.40	.14	.44	.38	.02 - .44
	Cl	%	.40	.35	.42	.42	.12 - .93
Wheat grain	Fe	ppm	55	61	60	50	25 - 380
% moisture	Mn	"	45	44	44	51	0 - 230
	Cu	"	10	8	8	9.7	3 - 22
	Zn	"	50	57	-	14	13 - 100
	Co	"	.05	.01	-	.07	.01 - .13
	Na	%	.08	.06	.06	.09	0 - .27
	Cl	%	.08	.08	.08	.07	.02 - .19

Table 12 (Continued) -- Micro-elements in Crops[a]

Crop	Nutrient	Unit	This Study	Beeson 1941	Morrison 1959	NRC 1968	Reported Ranges
Soybean seed	Fe	ppm	72	72	72	-	51 - 120
10% moisture	Mn	"	25	25	29	-	19 - 37
	Cu	"	15	11	16	-	11 - 16
	Zn	"	15	16	-	-	16
	Co	"	-	-	-	-	-
	Na	%	.22	.22	.22	-	.14 - .61
	Cl	%	.03	.03	.03	-	.03 - .04
Sugar beet roots	Fe	ppm	10	11	-	-	11
80% moisture	Mn	"	40	40	-	-	40
	Cu	"	2	2	-	-	2
	Zn	"	-	-	-	-	-
	Co	"	-	-	-	-	-
	Na	%	.09	.09	-	-	.05 - .15
	Cl	%	.09	.09	-	-	.01 - .18

a - See footnote, Table 10.

Table 13 -- Yield Goals and Removals of Micro-elements in Crops

Crop	Yield Goal	NUTRIENT						
		Fe	Mn	Cu	Zn	Co	Na	Cl
				lb/a				
Corn, grain	150 bu/a	.42	.08	.04	.13	.0003	3	3
Corn, silage	25 T/a	4.0	.75	.10	.25	.001	5	25
Alfalfa-brome	5 T/a	1.0	.5	.15	.4	.001	40	40
Wheat grain	60 bu/a	.2	.16	.04	.18	.0002	3	3
Soybean grain	35 bu/a	.15	.05	.03	.03	-	5	1
Sugar beets	25 T/a	.5	2	.10	-	-	45	45

c. Phosphorus

The chemistry of phosphorus removal from wastewater applied to land has been reviewed by Ellis, 1973, and particularly as it applies to one area of Eastern Michigan (Technical Report No. 30, Institute of Water Research, MSU, 1972). As has been pointed out, plant removal of phosphorus is very effective if the application rate is low. The precise quantity of phosphorus that can be removed in such a system has been estimated in Table 11. The estimates do not vary greatly from the observed values in the Pennsylvania State University study (Parizek, et al, 1967) although they are in general a little lower. The relationship between concentration of phosphorus in the final wastewater, rate of application and net phosphorus applied after crop removal is illustrated in Table 14. It is apparent from this table that quantities of water up to 120 inches per acre per year could be applied without exceeding greatly a soils ability to adsorb phosphorus if the wastewater contains only 2.5 or less ppm P. But at 7 ppm P any application rate exceeding 40 inches per acre per year is likely to give more phosphorus than can be removed by the soil.

Application rates of 120 inches per acre per year, as have been suggested by some individuals, would in 50 years exceed by many times the soil's ability to adsorb phosphorus. Even with some regeneration of adsorbing surfaces as is anticipated, it is most unlikely that this quantity of phosphorus can be removed from solution. And it would be expected that considerable phosphorus would move through the soils at these high levels of application.

Existing data for phosphorus adsorbing capacity for each of the soil associations or management groups that are in Southeastern Michigan are given in Table 15.

Table 14 -- Phosphorus applied to soils as a function of phosphorus concentration and rate of application of wastewater.

Water Applied	2.5 ppm P Concentration: P applied, Total	2.5 ppm: P applied, Net*	2.5 ppm: Net P applied, 10	2.5 ppm: Net P applied, 20	2.5 ppm: Net P applied, 50 yrs	7 ppm P Concentration: P applied, Total	7 ppm: P applied, Net*	7 ppm: Net P applied, 10	7 ppm: Net P applied, 20	7 ppm: Net P applied, 50 yrs
Acre inches per year	Pounds per acre-year		- - PoundsP/acre - -			Pounds per acre-year		- - PoundsP/acre - -		
10	5.6	(19.4)	(194)	(387)	(967)	15.8	(9.2)	(92)	(184)	(460)
20	11.3	(13.7)	(137)	(274)	(685)	31.6	6.6	66	132	330
30	17.0	(8.1)	(81)	(161)	(402)	47.4	22.4	224	448	1,120
40	22.6	(2.4)	(24)	(48)	(120)	63.2	38.2	382	764	1,910
50	28.2	3.2	32	65	162	79.0	54	540	1,080	2,700
60	33.9	8.9	89	178	445	94.8	69.8	698	1,396	3,490
70	39.5	14.6	146	291	727	111	85.6	856	1,712	4,280
80	45.2	20.2	202	404	1,010	126	101	1,010	2,030	5,070
90	50.8	25.8	258	516	1,290	142	117	1,170	2,340	5,860
100	56.5	31.8	318	636	1,590	158	133	1,330	2,660	6,650
120	67.8	42.8	428	856	2,140	190	165	1,650	3,290	8,230

*This assumes an average of 25 pounds per acre per year P removal by crops.

Table 15 -- Phosphorus adsorbing capacity of different soil management groups.

Soil Series & Management Group	Horizon	Texture	Depth	K	b	Fraction Available for Adsorption	P Adsorption Capacity: Acre Foot	P Adsorption Capacity: Acre Horizon
			Inches	$\times 10^{-4}$	mg/100g	%	- - - - - pounds	- - - - -
Ontonagon Obc	A_1	Clay	0-2	2.19	49	83	1,468	245
	A_2	Clay	3-6	3.81	33	90	1,072	357
	AB	Clay	7-12	5.41	29.4	92	976	488
	B_{21}	Clay	13-28	4.39	18.5	91	686	915
	B_{22}	Clay	29-34	4.00	14.9	90	547	273
	C	Clay	$>$ 34	4.12	14.3	90	525	88 to 36" 1,050 36-60"
							Total	3,416
Miami 2.5a	A_p	Loam	0-12	.95	20.6	68	506	506
	B	Clay Loam	13-30	5.77	12.1	93	459	688
	C	Loam to silt loam	31-60	7.26	17.4	94	667	333 to 36" 1,334 36-60"
							Total	2,861
Conover 2.5b	A_p	Loam	0-12	2.79	10.75	86	334	334
	B	Clay loam	13-30	8.06	20.25	95	784	1,176
	C	Loam to silt loam	31-60	5.25	13.5	92	506	253 to 36" 1,012 36-60"
							Total	2,775

Table 15 (Continued) -- Phosphorus adsorbing capacity of different soil management groups.

Soil series & Management Group	Horizon	Texture	Depth	K	b	Fraction Available for Adsorption	P Adsorption Capacity Acre Foot	P Adsorption Capacity Acre Horizon
			Inches	$x10^{-4}$	mg/100g	%	- - - - pounds	- - - - -
Brookston 2.5c	A_p	Loam	0-12	5.71	18.6	93	624	624
	B	Clay loam	13-48	6.56	16.0	94	613	1,226 to 36" 613 to 48"
	C	Loam to silt loam	49-60	2.93	14.1	87	500	500 to 60"
							Total	2,963
Hillsdale 3a	A	Sandy loam	0-24	3.22	12.7	88	403	806
	B	Sandy clay loam to sandy loam	25-46	5.02	11.1	92	416	416 to 36" 347 36-46"
	C	Sandy loam to loamy sand	47-60	3.74	11.0	89	399	466 46-60"
							Total	2,035
Locke 3b (Data estimated from Hillsdale)	A	Sandy loam	0-14	3.22	12.7	88	403	470
	B	Sandy clay loam	15-36	5.02	11.1	92	416	763
	C	Sandy loam	37-60	3.74	11.0	89	399	798 36-60"
							Total	2,031
Montcalm	A	Loamy sand	0-26	4.39	6.1	91	200	433
	B	Sandy loam	27-33	5.16	9.2	92	345	201
	C	Loamy sand	34-60	3.39	5.4	88	194	48 33-36" 388 36-60"
							Total	1,070

Table 15 (Continued) -- Phosphorus adsorbing capacity of different soil management groups.

Soil series & Management Group	Horizon	Texture	Depth	K	b	Fraction Available for Adsorption	P Adsorption Capacity Acre Foot		Acre Horizon	
			Inches	$x10^{-4}$	mg/100	%	- - - - pounds		- - - - -	
Spinks 4a	A	Loamy sand	0-20	1.63	12.2	79	348		580	
	B	Loamy sand to sand	21-50	1.02	21.2	70	605		807	to 36"
									706	37-50"
	C	Sand	51-60	2.38	8.0	84	274		228	51-60"
								Total	2,321	
Plainfield 5a	A	Loamy sand	0-20	4.57	7.6	91	249		415	
	B	Sand	21-50	1.82	11.8	80	386		515	to 36"
									450	37-50"
	C	Sand to fine sand	51-60	2.54	10.8	85	373		311	51-60"
								Total	1,691	
Granby 5c	A	Loamy sand	0-12	Field observation			396		396	
	B	Fine sand	13-30	"	"		396		594	
	C	Sand to fine sand	31-60	"	"		396		198	to 36"
									792	36-60"
								Total	1,980	
Fox-Kalamazoo 3/5a	A	Loam	0-12	.5	16.5	53	317		317	
	B	Gravelly clay loam to sandy clay loam	13-36	2.2	19.4	83	535		1,070	
	C	Sand & gravel	37-48	1.5	11.4	77	358		358	
			49-60	2.9	3.4	87	121		121	
								Total	1,866	

Table 15 (Continued) -- Phosphorus adsorbing capacity of different soil management groups.

Soil series & Management Group	Horizon	Texture	Depth	K	b	Fraction Available for Adsorption	P Adsorption Capacity Acre Foot	Acre Horizon
			Inches	$x10^{-4}$	mg/100g	%	- - - - pounds	- - - - -
Warsaw 3/5a	A	Sandy loam	0-15	3.0	18.5	87	581	726
	B	Sandy clay loam	16-34	4.9	37.3	92	1,399	2,215
	D	Sand & gravel	35-60	5.4	4.6	93	174	29 to 36"
								348 37-60"
							Total	3,318
Oshtemo 4/5a	A	Loamy sand	0-14	1.0	12.5	68	307	358
	B	Sandy loam to loamy sand	15-46	3.0	8.9	87	315	577 to 36"
								262 37-46"
	C	Sand & gravel	47-60	2.9	8.2	87	291	340
							Total	1,537
Muck	Field observation						117	351 to 36"
								234 37-60"
							Total	585
Roscommon (or Au Gres) 5b	A_1	Loamy sand	0-5	.4	12.5	50	226	94
	A_2	Sand	6-9	2.6	6.2	85	213	71
	B	Loamy sand	10-18	1.0	25.2	69	709	532
	B	Loamy sand	19-36	1.2	5.1	73	152	228
	C	Sand	37-60	2.5	4.6	83	154	308
							Total	1,233

Although many of the soil series encountered in Southeastern Michigan have not as yet been studied either in the laboratory or in the field, the range of soil management groups has been covered so that reasonable estimates of the adsorption capacity can be made for all of the desired soil associations. In general, the estimates of adsorption capacity have been made in the laboratory but a limited number of field observations have been included where laboratory data is not available. Values have been calculated and used to a five foot depth, but a division has been made at the three foot level to indicate the relative importance of the three to five foot layer of soil in removing phosphorus. In general this lower layer of soil is slightly lower in adsorbing capacity than the B horizon above it. In certain soils, Warsaw for example, this layer becomes coarse sand and gravel with a very low adsorption capacity.

The data in Table 15 were used to calculate the acre inches of water that could be applied to soils within each of the management groups. The values used for phosphorus removed by crops was taken from the Pennsylvania State study. Slightly more conservative estimates would have evolved from use of the data in Table 11. It should be emphasized that the calculated number of acre inches is from the viewpoint of phosphorus limitation only and that the actual quantity of wastewater that may be applied could be limited by some other factor, for example, hydraulic conductivity of the soil.

Those soils in management groups 0, 1, and 2.5 will remove phosphorus from 50 to 60 inches of wastewater per year (Table 16). However, the sandy soils (management groups 3, 4 and 5) will remove phosphorus from only 30 to 40 inches of wastewater per year. And the muck soils can use even less water.

Table 16 -- Quantity of effluent containing 7 ppm phosphorus that may be applied to various crops for 50 years and effectively remove phosphorus.

Management Group	Soil Series	P Adsorbing Capacity	C R O P*				
			Wheat	Corn	Alfalfa	Beans	Trees
		Pounds P/acre 5'	- - - - Acre inches of effluent/year - - - - -				
0a	Ontonagon	3,416	56	59	63	49	46
1.5a	Nester	2,972	50	53	58	43	40
2.5a	Miami	2,861	49	52	56	42	39
2.5b	Conover	2,775	48	51	55	41	38
2.5c	Brookston	2,963	50	54	58	44	41
3a	Hillsdale-Fox	1,866	36	39	44	29	27
3b	Locke	2,031	38	41	46	31	29
4a	Spinks	2,321	42	45	50	35	33
5a	Plainfield	1,691	34	37	42	27	25
5b	Au Gres	1,233	28	31	36	21	19
5c	Newton	1,980	38	41	45	31	28
Muck		585	20	23	28	13	11

*Assumes the following P removal per acre per year: Wheat 20, Corn 25, Alfalfa 32, Beans 9 and Trees 5.

d. Soluble Salts

The effect of wastewater application on the accumulation of soluble salts has been previously calculated for soils of Eastern Michigan (Technical Report No. 30, Institute of Water Research, MSU, 1972.) The conclusion is very applicable to this report. Namely, the sodium adsorption ratio will increase slightly under application of wastewater but it should stay well below the danger zone. Infiltration rates could be expected to become somewhat slower after prolonged application of wastewater but this should not be a major factor.

One situation being evaluated in this report requires special consideration. That is application of wastewater to soils in the management group 1.5. This study recognizes that these soils could receive wastewater in quantities that balance the evapotranspiration deficit during the summer months (approximately 12.5 acre inches of water per year). But it would not be expected that excess water could be leached through these soils to remove the excess salts because of the soil's low hydraulic conductivity. Thus any excess of salts beyond plant uptake will accumulate in the soil. This effect is illustrated in Table 17. It is apparent that there will develop a large potassium deficit but the other ions associated with soluble salts will accumulate. This may require the growth of salt tolerant crops and intermittent periods of no irrigation to allow for a few years to reduce salt levels in the soil by plant uptake. This deficit or accumulation will be over the five foot depth of soil. Thus, the 5,400 pounds per acre potassium deficit will be for the profile; but, only soil analysis will be capable of determining the exact distribution

Table 17 -- Soluble salt balance within a soil with wastewater irrigation and restricted drainage

Ion	Concentration in Effluent	Quantity Applied*	Crop Removal	NET ACCUMULATION Each year	Total for 50 years
	ppm	lbs/acre			
Ca	70	198	45	153	7,650
Mg	35	99	30	69	3,450
Na	120	339	12	327	16,350
K	15	42	150	(108)	(5,400)
Cl	184	520	15	505	25,250

*Quantity applied each year in 12.5 acre inches of wastewater.

and the necessity for correction of potassium deficiency by supplemental fertilization. The net accumulation of sodium chloride will be more likely to be uniformly distributed through the entire profile. But the concentration is expected to become high.

e. Heavy Metals, Micronutrients, Lime

Knezek has assessed the probable impact of 13 micronutrients and heavy metals on soils and crops in waste disposal systems (Technical Report No. 30, Institute of Water Research, MSU, 1972). It was pointed out that effluent additions would greatly exceed crop removal, a point which is illustrated by data for the few elements considered in Table 13.

The profile for the effluent considered in the earlier report was essentially the same as that in Table 8. The possibility that boron might be toxic to some crops was pointed out. The 3 pounds of B calculated for 20 inches of effluent in Table 8 is the maximum recommendation in Bulletin E-550 for correcting deficiencies in responsive crops (alfalfa, sugar beets). If this quantity were used in a banded fertilizer application for sensitive crops (beans, soybeans, small grains), it would almost certainly produce severe injury. Broadcast applications of 3 pounds or more on pea beans have produced toxic symptoms, whereas up to 8 or 10 pounds were broadcast on soybeans before toxic effects were produced (Robertson, 1972, unpublished data).

While there is a potential hazard to sensitive crops from boron, the conditions of application in wastewater will greatly minimize the hazard. Annual inputs will be distributed, in small increments not exceeding 1/2 pound B in 2" of irrigated wastewater, over 7 to 8 months of the year. Effective concentrations

will be attenuated by leaching, redistribution through larger volumes of soil and by reversion to complexed forms not directly available for uptake by plants. The direct application proposed for the most sensitive crop (pea beans, Table 19-a) is 2" of effluent, or less than 1/2 pound B. Soybeans would receive up to 19 inches of effluent (3 to 4 pounds B) on coarse-textured soils (Table 20-a). Perhaps the most problematic situation would be that for wheat on coarse-textured soils (38 inches, or up to 8 pounds B). However, this total would be distributed over a 10-month period, and a net downward flux of water would minimize accumulation of soluble boron in the root zone.

There remains the possibility that the boron-adsorbing capacity of soils may be saturated after a few years and that the concentration in soil solution and percolating water will approach that of the applied effluent. Consideration should be given to identifying and reducing sources of the boron which appears in waste effluent.

Another possible nutritional problem stems from the rather high concentration of iron in the effluent, particularly if the ratio of Fe to Mn or Zn is high. Deficiencies of Mn in beans and sugar beets or Zn in beans and corn may be accentuated on certain lake bed or glacial outwash soils, as well as on acid soils if excessive quantities of lime are used to correct acidity. Such deficiencies are readily identified and can be corrected. (Bul. E-550).

With the possible exception of boron, there is little likelihood that any of the micronutrients or heavy metals in the effluent of Table 8 will accumulate to dangerous levels in plants or move into drainage in concentrations to exceed drinking water standards. Most will be immobilized by interacting with mineral

AD-A041 125 MICHIGAN STATE UNIV EAST LANSING DEPT OF CROP AND SO--ETC F/G 13/2
LAND TREATMENT OF WASTEWATER IN SOUTHEASTERN MICHIGAN.(U)
JUL 73 DACW35-73-C-0163

UNCLASSIFIED NL

2 OF 3

AD
A041125

and organic colloids, most probably in the plow layer.

As noted in Tech. Rep. No. 30, toxic activities will be reduced and stabilization of heavy metals promoted by maintaining soil pH near neutrality. Liming acid soils to pH 6.5 is recommended here. It appears inadvisable to correct to a higher pH, since retention of bases from the effluent may lead to further increases in soil pH. The extent to which this may or may not occur will depend on exchange capacity and mineralogy of the soil and on the composition and properties of effluent from a specific source.

f. Organic Matter

The organics in the effluent will include low molecular weight fulvic acids and synthetic chelating agents, representing perhaps as much as 1/3 of the input COD (Tech. Rep. 30), or of the order of 1-1/3 lb/a/inch of chelating substances (60 lb/a at 45"). These will increase the mobility and availability to plants of cationic nutrients and heavy metals.

The management criteria proposed here includes the requirement that well-aerated root zones must be maintained for optimum root function and that the soil profile should be dewatered periodically to maintain the water-permeability of subsoils. These conditions will promote the stabilization of mobile minerals and complexes by dehydrative and oxidative mechanisms. In addition, the systems should be managed to maximize return of crop residues. Actively decomposing organic matter is the source of microbial products which stabilize soil structure (essential for aeration, infiltration and water permeability) and which enter into immobile humic complexes with minerals.

This concern for maintaining adequate organic additions favors (1) keeping the soil under sod as much as possible, (2) harvest of corn for grain rather than silage, (3) return of straw from small grains, directly or after use as bedding for livestock, (4) return of rye or other winter cover rather than harvesting it for silage, and (5) introduction of organics from other sources (pulping wastes, wood wastes, recycled fibers, etc.). These and other possibilities may not be practical in all situations, but in each local case every opportunity should be exploited for periodic additions of readily decomposable organic matter into the soil system.

3. <u>Drainage</u>

It is mandatory that adequate drainage be provided on all soils receiving secondary municipal effluent. A drainage system will not only enhance the water infiltration rate, provide accessibility for sampling ground water and testing the efficiency of the water renovating processes in the soil, but will also assure a well aerated soil that is necessary for renovation of wastewater and crop production.

Although drainage systems may take on many forms, the one most commonly used on somewhat poorly and poorly drained soils in Southeastern Michigan is subsurface tile drainage. Its primary advantage is that it does not hinder machine movement in the field. Tile should be placed as deep as possible (at least five feet) to maximize the aeration zone. Short spacings between tile lines (50 feet or less) will enhance the drainage capacity and increase the depth of the aeration especially at the critical point midway between tile lines. Other factors considered in drain design equations are the hydraulic conductivity of the soil, and the average rate at which water is applied to the soil by irrigation or rainfall. Assuming a tile depth of 5 feet,

tile spacing of 50 feet, an impervious soil layer at 6 feet, a hydraulic conductivity of 1 inch/hour, and an average weekly flux (drainage water) of 2 inches, the water table at the mid-point between two tile lines will be 3 feet from the soil surface. Because of a capillary fringe not all of the soil will be well aerated down to this depth. During the summer months when evapotranspiration is at a maximum, the soil may tolerate 4 inches of water per week under the conditions given above.

In many finer textured,poorly drained soils (1.5c) the hydraulic conductivity will be well below 1 inch per hour. Good soil management practices such as minimum tillage, crop rotations, and the incorporation of large amounts of organic matter will help stabilize soil structure and maximize the hydraulic conductivity. Poor soil management, on the other hand, will further deteriorate the present hydraulic capacity.

Tile systems are not customarily used in well drained or moderately well drained soils. In some of these soils, the water table may rise sufficiently under intensive sprinkling to warrant the installation of a tile system to remove excess water. Another possibility is the installation of a series of wells which when pumped periodically will lower the water table sufficiently.

Wherever possible, advantage should be taken of subsurface lateral flow of water. Evidence of such flow is frequently seen as seepage from higher elevations. If sufficiently renovated, this water may be permitted to flow into a deeper aquifer or into interceptor tiles, ditches or naturally occurring streams. The monetary saving from such systems in reduced installation and maintenance costs is readily apparent. Tile or trenches may play a special role in seepage systems by keeping the seepage waters from coming to the soil surface and

creating an anaerobic, excessively wet zone.

Care must be exercised that sprinkled water does not short circuit or by-pass the living filter. This can occur momentarily if water is applied to dehydrated fine-textured soils (large cracks). It can also occur where a coarse fill material is used in backfilling the tile lines. The soil renovation process can also be by-passed by irrigating slopes in excess of 6 percent, exceeding the infiltration capacity of the soil, or considering any management practice that will limit the aerobic zones within the soil. Anaerobic conditions that may solubilize phosphates and some minor elements will enhance rather than minimize the overall problem of wastewater renovation.

The movement of water in soil both in the saturated and unsaturated phase is in general agreement with Darcy's law. The major driving forces of the water movement in soil are gravity and soil matric suction, the latter being of minimum importance in an intensively irrigated area. The infiltration rate at equilibrium is comparable to the saturated hydraulic conductivity (Ks). The unsaturated hydraulic conductivity (K) is a function of moisture content. It is not uncommon to have a 50% reduction in K for each unit percent decrease in moisture content. Hence as a soil loses its water content with time it also loses its capability to transmit the remaining water held in the soil to the drainage system. The point that should be made here is that it is erroneous to accept only the saturated conductivity for design and drainage analysis considerations.

4. Cropping Systems, Irrigation Schedules and Fertilizer Requirements.

a. Cropping Systems and Irrigation Schedules

The cropping systems and irrigation schedules (Tables 18-a and 18-b) were developed assuming that the fine and intermediate textured soils would be tile drained with adequate outlets so as

to insure an aerated zone of five feet at all times. This is primarily to give adequate renovation of the waste but also would greatly benefit the crops grown on the imperfectly drained and poorly drained soils. It would also improve the ease of farming in periods of excess rainfall. It has also been assumed that soils of greater than 6% slope would be an erosion hazard and are not considered.

In order to protect the soil surface at all times so as to maintain the infiltration in the soils the cropping systems include cover crops at all times. Rye is proposed for a cover because of its fast germination, durability, cool weather growth and controllability. It should be easy to establish the rye cover with the availability of wastewater irrigation for germination. Corn and other crops should be planted with high populations and narrow rows to give a maximum cover and maximum utilization of nutrients.

No soil manipulations or harvesting can be done while the soil is wet or moist enough for the soil to be compacted by the operation. Any manipulation which would cause a degradation of structure could seriously reduce the infiltration of water. Minimum tillage should be practiced in order to assure maximum infiltration rates.

These Tables (18-a and 18-b) have been derived from the best available data and experience. There is a need for research demonstration farms to be established to prove that these cropping systems and irrigation schedules are feasible. This proof is necessary before implementation of this system. Such research will take three to five years to accomplish if any variability in weather patterns are to be studied.

Table 18-a -- Cropping Systems and Irrigation Schedules for Various Soil Management Groups

Soil Management Group 1abc, Tile Drained -- Typical Soils -- St. Clair, Nappanee, Hoytville. No wastewater application recommended.

Soil Management Group 1.5abc -- Tile Drained -- Typical Soils -- Morley, Blount, Pewamo. Crops: Corn, Beans, Wheat, Alfalfa-brome. Ten to fifteen inches of effluent applied to meet the evapotranspiration deficit during the growing season.

Soil Management Group 2.5abc, Tile Drained, 0-6% slope -- Typical soils -- Miami, Conover, Brookston.

Crop - Corn (rye)

Time Period	Operation	Amount of Effluent Applied Inches
April	Overwintered rye	2
May 10-15	Rye silage harvest Plow Plant corn	
May 16-30		2
June		3
July		5
August	Seed rye	5
September		2
October 1-15	Harvest corn for grain*	
October 16-30		2
November		4
	Total	25 inches

*If corn is harvested for silage no application is made in September before and during harvest. Four inches of effluent is applied in October.

Table 18-a (Continued

Soil Management Group 2.5abc (continued). Tile drained, 0-6% slope.
Typical soils -- Miami, Conover, Brookston.

Crop - Soybeans (rye)		
Time Period	Operation	Amount of Effluent Applied Inches
April	Overwintered rye	4
May 1-15		3
May 16-25	Harvest rye silage	
May 26-June 5	Plow Plant soybeans	
June 6-30		3
July		4
August		2
September 1-15	Harvest soybeans	
September 16-30		2
October		3
November		4
	Total	25 inches

If dry beans in June and August no effluent application will be made and only 2 inches in July.

Crop - Wheat (Alfalfa-brome)		
Time Period	Operation	Amount of Effluent Applied Inches
September 10-20	Corn silage harvest or Soybean harvest	
September 21-30	Disk and plant wheat	2
October		3
November		4
April	Seed alfalfa-brome	2
May		4
June		4
July 1-15	Wheat ripening	
July 15-August 15	Harvest wheat	
August 16-30	Alfalfa-brome	3
September		4
October		3
November		2
	Total for 15 months	31 inches*

*Total for year September 1 to August 31, or April 1 to November, is 22 inches for year.

Table 18-a (Continued)

Soil Management Group 2.5abc (continued). Tile drained, 0-6% slope.
Typical soils - Miami, Conover, Brookston

Crop - Alfalfa-brome - Year of seeding without nurse crop		
Time Period	Operation	Amount of Effluent Applied Inches
April		2
May	Prepare soil, plant Alfalfa-brome	2
June		3
July		4
August		4
September		4
October		3
November		3
	Total	25 inches

Crop - Alfalfa-brome - Each harvest year		
Time Period	Operation	Amount of Effluent Applied Inches
April		2
May		4
June	Harvest, then irrigate	3
July	Harvest	4
August	Harvest	4
September	(Harvest?)	3
October		3
November		2
	Total	25 inches

Soil Management Group 2.5 bc. Tile drained.
Typical soils -- Conover, Capac, Brookston, Parkhill.

Crop - Sugar Beets		
Time Period	Operation	Amount of Effluent Applied Inches
April	Plow Plant Sugar Beets	None
May		2
June		4
July		5
August		5
September 1-20		None
September 21-October 20	Harvest Sugsr Beets Plant Rye	
October 21-30		1
November		4
	Total	21 inches

Table 18-a (Continued)

Soil Management Group 3abc. Tile drained, 0-6% slope.
Typical soils - Hillsdale, Teasdale, Barry.

Crop - Corn (Rye)		
Time Period	Operation	Amount of Effluent Applied
April		3 inches
May 10-15	Rye for silage	
	Plow	
	Plant corn	
May 15-30		3
June		6
July		8
August	Seed rye	8
September 1-15		4
October 1-15	Harvest corn for grain*	
October 16-30		3
November		5
	Total	40 inches

*If corn is to be harvested for silage apply no effluent in September before and during harvest and 7 inches after harvest and during October.

Crop - Soybeans (Rye)		
Time Period	Operation	Amount of Effluent Applied Inches
April	Rye	4
May 1-15	"	4
May 16-25	Harvest rye silage	
May 26-June 5	Plow and plant soybeans	
June 6-30		5
July		8
August		6
September 1-15	Harvest soybeans	
September 15-30	Plant wheat	3
October		5
November		5
	Total	40 inches

Table 18-a (Continued)

Soil Management Group 3abc (continued). Tile drained, 0-6% slope.
Typical soils - Hillsdale, Teasdale, Barry.

Crop - Wheat (Alfalfa-brome)		
Time Period	Operation	Amount of Effluent Applied Inches
September 10-20	Harvest corn silage or soybeans	None
September 21-30	Disk and plant wheat	3
October		5
November		5
April	Seed alfalfa-brome	3
May		6
June		7
July 1-15		3
July 16-August 15	Harvest wheat	None
August 16-30		4
September		6
October		6
November		5
	Total for 15 months	53 inches*

*Total for year September 1 to August 30 is 36 inches, or April 1 to November 30 is 40 inches.

Crop - Alfalfa-brome, seeded alone		
Time Period	Operation	Amount of Effluent Applied Inches
April		2
May	Prepare soil, plant	3
June		6
July		6
August		6
September		6
October		6
November		5
	Total	40 inches

Crop - Alfalfa-brome each harvest year		
Time Period	Operation	Amount of Effluent Applied Inches
April		4
May		6
June	Harvest	6
July	Harvest	6
August	Harvest	6
September	(Harvest ?)	6
October		6
November		5
	Total	45 inches

Table 18-a (Continued)

Soil Management Group 3/5abc. Tile drained, 0-6% slope.
Typical soils - Fox, Kalamazoo, Matherton, Sebewa.
Crops: Corn, soybeans, wheat and alfalfa-brome.
Irrigate as Soil Management Group 2.5abc because of the dense subsoil. If the subsoil is modified by deep mixing the soil to the depth of the dense subsoil with a disk plow these soils could be treated as Soil Management Group 3.

Soil Management Group 4ab. Tile or pump drained.
Typical soils: Spinks, Thetford.
Crops: Corn, soybeans, wheat and alfalfa-brome.
Irrigate as Soil Management Group 3abc because the phosphate sorption limitation of these soils is 40 inches of effluent per year.

Soil Management Group 5abc. Tile or pump drained.
Typical soils - Plainfield, Tedrow, Newton.
Crops: Corn, wheat, soybeans and alfalfa-brome.
Irrigate as Soil Management Group 2.5abc but increase the application rate by the factor 1.4.

Table 18-b -- Summary of Annual Effluent Application rates by Soil Management Groups and Crops

Soil Management Group	Corn	Soybeans	Wheat	Alfalfa-brome	Average
	- - - - - - - - - - - -	Inches/Year	- - - - - - - - - - - -		
0 & 1					
1.5	10-15 inches depending on moisture deficit.				12.5
2.5	25	25 Dry beans 18 Sugar beets 21	22	25	25
3	40	40	36	45	40
3/5	Either like 2.5 or 3 depending on subsoil tillage.				(25) or 40
4/2	25	25	22	25	25
4	40	40	36	45	40
5	35	35	31	35	35

b. Fertilizer Requirements

Effluent irrigations scheduled in Table 18 will not supply N required for the desired high yields of several crops nor K to replace that removed in corn silage, alfalfa-brome or sugar beets. Management principles and fertilizer recommendations outlined in Michigan Ext. Bul. E-550 are used as the basis for estimating fertilizer requirements in Tables 19 and 20.

The calculations in these tables are illustrative. The derived estimates of needed fertilizer apply only to the soil test levels and management parameters specified in each table. The K requirements in Table 19 for loam soils apply also to clay loams and clays, those in Table 20 apply to sandy loams and coarser textured soils.

In principle, the total requirement for supplemental N, P or K, taken from Bul. E-550, is adjusted by subtracting the amounts added in effluent applied in fall and early spring on sod or cover crop and in effluent applied directly on the crop during the growing season. It is assumed that half the nutrients applied in fall and early spring will be removed if the cover crop is harvested for silage.

Where corn follows alfalfa-brome (Tables 19-c, 20-c) the legume is credited with a carryover contribution of 80 lb. N per acre, rather than 60 as suggested in the bulletin. This assumes a vigorous legume component in the mixture and a 5-ton level of yield.

If livestock manure is applied, it will contribute N, P and K in quantities varying with class of livestock, management, etc. (Bul. E-550, Table 12.) These contributions should be deducted

from the fertilizer application for the succeeding crop.

The calculations of Tables 19 and 20 verify the expectation that no fertilizer P will be needed, with the possible exception of crops with a high P requirement, such as sugar beets, or on soils very low in available P and with a high P fixing capacity.

Consideration should be given to adding fertilizer N and K in the irrigation water. Such additions should be regulated to meet the actual needs of the crop as determined by stage of growth and by visual observations and quick tissue tests in the field. Increased efficiency in utilization by the crop will reduce the quantities of fertilizer nutrients needed.

Timed applications of N, adjusted to crop need, will greatly reduce risks associated with excessive seasonal accumulations of nitrate. It is important to control the seasonal distribution of nitrate in the soil to minimize leaching movement and also to avoid adverse effects on quality of crops like sugar beets which result when the availability of N during the latter half of the growing season is excessive.

Table 19-a -- Fertilizer requirements for optimum yields of soybeans or pea beans.

Soils: 2.5abc (Brookston, Conover, Miami)

Previous crop: Corn, sugar beets or small grain followed by rye cover receiving 6" effluent in fall, 7" in spring, total 13".

Nutrient	Removed in 35 bu. Beans	Required for 35 bu/a beans		Estimated Carryover from Rye (13" effluent) Lb/a	Supplied by Effluent on Beans		Apply as Fertilizer Lb/a
		Bull. E-550 basis	Lb/a		Water In.	Nutrient Lb/a	
A. If rye cover is plowed down:							
N	120	Table 6, no manure or legume	60	29	9 2	20 4	20 30
P	12	Table 8, soil test: 40-59	11	20	9 2	14 3	0 0*
K	36	Table 10, soil test: 160-209	21	25	9 2	17 4	0 0*
B. If rye is removed for sileage:							
N	120	(same basis)	60	14	9 2	20 4	35 45
P	12	" "	11	10	9 2	14 3	0 0*
K	36	" "	21	12	9 2	17 4	0 0*

*some fertilizer P and/or K may be needed at lower soil test levels

Table 19-b -- Fertilizer requirements for optimum yields of corn after row crop or small grain.

Soils: 2.5abc (Brookston, Conover, Miami)

Previous crop: Corn, soybeans, sugar beets or small grain followed by rye cover receiving 6" effluent in fall, 2" in spring, total 8".

Nutrient	Removed in grain or silage	Required for 150 bu. corn or 25 ton silage		Estimated Carryover from rye 8" Effluent Rye plowed down	Supplied by Effluent on Corn		Apply as Fertilizer
		Bull. E-550 basis	Lb/a	Lb/a	Water In.	Nutrient Lb/a	Lb/a
A. Corn for grain							
N	125	Table 5, no manure or legume	175	18	15	33	125
P	22	Table 8, soil test: 40-59	33	13	15	24	0*
K	28	Table 10, soil test: 170-209	62	15	15	29	0*
B. Corn for silage							
N	165	(same basis)	200	18	15	33	150
P	30	" "	33	13	15	24	0*
K	150	" "	62	15	15	29	110*

*Need for fertilizer P and/or K will vary with soil test and average annual effluent application. Objective should be to achieve and maintain the indicated soil test levels and a favorable balance of exchangeable K, Ca and Mg.

Table 19-c -- Fertilizer requirements for optimum yields of corn after alfalfa-brome.

Soils: 2.5abc (Brookston, Conover, Miami)

Previous crop: Alfalfa-brome, receiving 5" effluent after harvest in fall, 2" in spring, total 7".

Nutrient	Removed in grain or silage	Required for 150 bu. corn or 25 ton silage		Estimated Carryover from alfalfa-brome (7" effluent)	Supplied by Effluent on Corn		Apply as Fertilizer
		Bull. E-550 basis	Lb/a	Lb/a	Water In.	Nutrient Lb/a	Lb/a
A. Corn for grain							
N	125	Table 5, no manure or legume	175	15 + 80#	15	33	50
P	22	Table 8, soil test: 40-59	33	11	15	24	0*
K	28	Table 10, soil test: 170-209	62	14	15	29	0*
B. Corn for silage							
N	165	(same basis)	200	15 + 80#	15	33	75
P	30	" "	33	11	15	24	0*
K	150	" "	62	14	15	29	110*

*Need for fertilizer P and/or K will vary with soil test and average annual effluent application. Objective should be to achieve and maintain the indicated soil test levels and a favorable balance of exchangeable K, Ca and Mg.

#Estimated carryover includes N in 7" effluent plus 80 lb N released from decomposing alfalfa residues.

Table 19-d -- Fertilizer requirements for optimum yields of wheat.

Soils: 2.5abc (Brookston, Conover, Miami)

Previous crop: Corn for silage or soybeans. 7" effluent on wheat in fall, 10" during harvest season, 17" total on wheat

Nutrient	Removed in 60 bu. Wheat	Required for 60 bu. wheat		Estimated Carryover	Supplied by Effluent on Wheat		Apply as Fertilizer
		Bull. E-550 basis	*Lb/a*	*Lb/a*	*Water In.*	*Nutrient* Lb/a	Lb/a
N	72	Table 6, no legume or manure	60	-	17	38	20
P	13	Table 8, soil test: 40-59	22	-	17	27	0
K	14	Table 10, soil test: 160-199	42	-	17	33	0

Table 19-e -- Fertilizer requirements for optimum establishment of alfalfa-brome without nurse crop.

Soils: 2.5abc (Brookston, Conover, Miami)

Previous crop: Corn, soybeans, sugar beets or small grain followed by rye cover crop receiving 6" effluent in fall, 4" in April, 10" total.

Nutrient	Removed None (No harvest)	Required for establishing alfalfa-brome seeding for 5 ton yield potential		Estimated Carryover from rye (10" effluent) Rye plowed down	Supplied by Effluent on Seeding		Apply as Fertilizer*
		Bull. E-550 basis	Lb/a	Lb/a	Water In.	Nutrient Lb/a	Lb/a
N	-	p. 15	0	22	23	51	0
P	-	p. 15 and Table 8, soil test: 40-59	22	16	23	36	0
K	-	p. 15	80	20	23	70	80#

*On acid soils, dolomitic lime to bring soil to pH 6.5 should be incorporated, preferably a year or two prior to seeding alfalfa.

#Full K requirement should be applied at planting time, 1/2 broadcast and worked in, 1/2 through grain drill at time of seeding. (Total K in effluent plus fertilizer exceeds requirement for establishment but contributes to overall maintenance of soil K.)

Table 19-f -- Fertilizer requirements for optimum yields of established alfalfa-brome.

Soils: 2.5abc (Brookston, Conover, Miami)

Previous crop: (Each harvest year after establishment.)

Nutrient	Removed in 5 ton hay	Required for 5 ton alfalfa-brome hay		Estimated Carryover (Does not apply)	Supplied by Effluent on Alfalfa-brome		Apply as Fertilizer Lb/a
		Bull. E-550 basis	Lb/a		Water In.	Nutrient Lb/a	
N	220	p. 15	0	-	25	56	0
P	30	Table 8, soil test: 40-59	11	-	25	40	0
K	166	Table 10, soil test: 170-209	62	-	25	48	120*

*Actual fertilizer K application should be adjusted by soil test to achieve or maintain a soil test of 170-209 lb K/acre.

Table 19-g -- Fertilizer requirements for optimum yields of sugar beets.

Soils: 2.5abc (Brookston, Conover, Miami)

Previous crop: Corn, soybeans or small grain followed by rye cover receiving 6" effluent in the fall.

Nutrient	Removed in 25 ton beets	Required for 25 ton beets		Estimated Carryover from Rye (6" Effluent)	Supplied by Effluent on Beets		Apply as Fertilizer
		Bull. E-550 basis	Lb/a	Rye plowed down Lb/a	Water In.	Nutrient Lb/a	Lb/a
N	104	Table 7, no manure or legume					
		a) after corn	20	13	16#	36#	10*
		b) after soybeans or small grain	60	13	16	36	20
P	18	Table 8, soil test: 60-70	55	10	16	25	20**
K	140	Table 10, soil test: 170-209	62	12	16	31	100**

*Starter quantities of N may be needed to get beets started vigorously.

#It may be necessary to reduce or eliminate July and August irrigations to avoid reduced sugar recovery due to late season excess of N.

**Adjust fertilizer P and K applications as soil tests vary from those indicated.

Table 20-a -- Fertilizer requirements for optimum yields of soybeans

Soils: 3abc (Barry, Teasdale, Hillsdale, Locke)

Previous crop: Corn or small grain followed by rye cover receiving 12" effluent in fall, 8" in spring, 20" total.

Nutrient	Removed in 35 bu. beans	Required for 35 bu./a beans		Estimated Carryover from Rye (20" effluent)	Supplied by Effluent on Soybeans		Apply as Fertilizer
		Bulletin E-550 basis	Lb/a	Lb/a	Water In.	Nutrient Lb/a	LB/a
A. If rye cover is plowed down:							
N	120	Table 6, no manure or legume	60	44	19	42	0
P	12	Table 8, soil test: 40-59	11	32	19	30	0
K	36	Table 9, soil test: 120-169	62	39	19	37	0
B. If rye is removed for silage:							
N	120	(same basis)	60	22	19	42	0
P	12	" "	11	16	19	30	0
K	36	" "	62	20	19	37	0

Table 20-b -- Fertilizer requirements for optimum yields of corn after row crop or small grain.

Soils: 3abc (Barry, Teasdale, Hillsdale, Locke)

Previous crop: Corn, soybeans or small grain followed by rye cover receiving 12" effluent in fall, 3" in spring, 15" total.

Nutrient	Removed in grain or silage	Required for 150 bu. corn or 25 ton silage		Estimated Carryover from rye (15" effluent)	Supplied by Effluent on Corn		Apply as Fertilizer
		Bull. F-550 basis	Lb/a	Rye plowed down Lb/a	Water In.	Nutrient Lb/a	Lb/a
A. Corn for grain							
N	125	Table 5, no manure or legume	175	33	27	60	85
P	22	Table 8, soil test: 40-59	33	24	27	43	0
K	28	Table 9, soil test: 120-169	125	29	27	52	45*
B. Corn for silage							
N	165	(same basis)	200	33	27	60	110
P	30	" "	33	24	27	43	0
K	150	" "	125	29	27	52	70*

*Fertilizer K needed will vary with soil tests, volumes of effluent applied and removals in crop. Objective should be to achieve and maintain the indicated soil test and a favorable balance of exchangeable K, Ca and Mg.

Table 20-c -- Fertilizer requirements for optimum yields of corn after alfalfa-brome.

Soils: 3abc (Barry, Teasdale, Hillsdale, Locke)

Previous crop: Alfalfa-brome, receiving 11" effluent after harvest in fall, 4" in April, 15" total.

Nutrient	Removed in grain or silage	Required for 150 bu. corn or 25 ton silage after alfalfa-brome		Estimated Carryover from alfalfa-brome (15" effluent)	Supplied by Effluent on Corn		Apply as Fertilizer
		Bull. E-550 basis	Lb/a	Lb/a	Water In.	Nutrient Lb/a	Lb/a
A. Corn for grains							
N	125	Table 5, no manure or legume	175	33 + 80*	27	60	0
P	22	Table 8, soil test: 40-59	33	24	27	43	0
K	28	Table 9, soil test: 120-169	125	29	27	52	45#
B. Corn for silage							
N	165	(same basis)	200	33 + 80*	27	60	25
P	30	" "	33	24	27	43	0
K	150	" "	125	29	27	52	70#

*Estimated carryover includes N in effluent applied since last harvest of alfalfa-brome plus 80 lb. N released from decomposing residues.

#Adjust fertilizer K as indicated by soil test to achieve and maintain the indicated soil test level and a favorable balance of exchangeable K, Ca and Mg.

Table 20-d -- Fertilizer requirements for optimum yields of wheat.

Soils: 3abc (Barry, Teasdale, Hillsdale, Locke)

Previous crop: Corn for silage or soybeans. 13" effluent in fall, 21" during harvest season, 32" total on wheat.

Nutrient	Removed in 60 bu. wheat	Required for 60 bu. wheat		Estimated Carryover	Supplied by Effluent on Wheat		Apply as Fertilizer
		Bull. E-550 basis	Lb/a	Lb/a	Water In.	Nutrient Lb/a	Lb/a
N	72	Table 6, no legume or manure	60	-	32	71	0
P	13	Table 8, soil test: 40-59	22	-	32	51	0
K	14	Table 9, soil test: 120-169	83	-	32	62	0

Table 20-e -- Fertilizer requirements for optimum establishment of alfalfa-brome without nurse crop.

Soils: 3abc (Barry, Teasdale, Hillsdale, Locke)

Previous crop: Corn, soybeans or small grain followed by rye cover crop receiving 13" effluent in fall, 4" in spring, 17" total.

Nutrient	Removed None (no harvest)	Required for establishing alfalfa-brome seeding for 5 ton yield potential		Estimated Carryover from rye (17" effluent)	Supplied by Effluent on Seeding		Apply as Fertilizer (Note requirement for lime)*
		Bull. E-550 basis	Lb/a	Rye plowed down Lb/a	Water In.	Nutrient Lb/a	Lb/a
N	-	p. 15	0	38	38	84	0
P	-	p. 15 and Table 8, soil test: 40-59	22	27	38	60	-
K	-	p. 15	80	33	38	73	40#

*On acid soils, dolomitic lime to bring soil to pH 6.5 should be incorporated, preferably a year or two prior to seeding alfalfa.

#One-half of K requirement should be supplied in fertilizer through grain drill at time of seeding. (Total K in fertilizer plus effluent exceeds requirement for establishment but contributes to overall maintenance of soil K.)

Table 20-f -- Fertilizer requirements for optimum yields of established alfalfa-brome.

Soils: 3abc (Barry, Teasdale, Hillsdale, Locke)

Previous crop: (Each harvest year after establishment.)

Nutrient	Removed in 5 ton hay	Required for 5 ton alfalfa-brome hay		Estimated Carryover	Supplied by Effluent on Alfalfa-brome		Apply as Fertilizer
		Bull. E-550 basis	Lb/a	Lb/a	Water In.	Nutrient Lb/a	Lb/a
N	220	p. 15	0	-	45	100	0
P	30	Table 8, soil test: 40-59	11	-	45	72	0
K	166	Table 9, soil test: 120-169	125	-	45	87	80*

*Actual fertilizer K application should be adjusted by soil test to achieve or maintain the indicated soil test (120-169 lb K/a). Excessive K may induce deficiencies of Mg and/or Ca on some soils. Such deficiencies would be reflected in excessively high tissue tests for K. Plant symptoms and soil tests for exchangeable K, Ca and Mg would help identify the specific deficiency (Sp. Bul. 353 and Bul. E-550). Total analysis of forage samples might be necessary in some cases.

5. Summary and Conclusions

The major objective of this study was to develop data and/or estimates of all factors which would determine the quantity of wastewater which could be applied to agricultural soils in Southeastern Michigan and still maintain maximum production while renovating the water. This data could then be utilized to develop irrigation zones within the region which would have common properties, such as distance from source of water, distribution of crops grown with irrigation, soil associations, etc. To allow for easiest combination of soil associations to produce irrigation zones our data has been tabulated by county and soil association. This data is presented in Tables 21-a to 21-y. All figures were rounded to nearest thousand acres or if less than 10,000 acres to the nearest two significant figures. Rounding was accomplished after multiplication so that the final figures of the quantity of water that can be applied by county and soil association are accurate as quoted.

The agricultural acres by soil association that will come under production if irrigated was estimated earlier in this report. To obtain an estimation of the useable acres the quantity or organic soils and other areas that could not be effectively drained together with those soils with greater than 6 percent slope were subtracted. The expected crop distribution from Table 7 was then combined with the usable acres to give the acres of each crop within each county by soil association. Estimates of the percentage distribution of each soil management group within each soil association (by county) was combined with the acre inches of water that each management group could receive per year to establish an average rate of water application

for each soil association. This does not imply that this quantity of water should be applied to all acres within the soil association, since the sandy soils in the association will actually receive much higher application rates than the fine textured soils. But rather this is the average that will be applied within the association. The total quantity of water that can be applied within each soil association was determined by multiplication of the usable acres by an average value of water that could be applied to crops on the average.

Irrigation schedules that may be used for each crop within each soil management group are developed and presented in Table 18-a and summarized in Table 18-b. In practice, some modification would need to be made for precipitation during an individual year since the tables prepared are for an "average" year.

It must be reemphasized that the figures for application rates and irrigation schedules given in this report are the "best estimate" of people knowledgeable in the field. But research work is non-existent in the area of spreading wastewater onto fine textured soils in a cool, humid region. This research must be accomplished before further development of wastewater irrigation systems in these regions.

Although the data reported herein were developed for use in planning waste disposal systems for the Detroit area, it should be pointed out that it would be equally useful for other cities in the area, both large and small. Although the detail is insufficient to allow direct use by small communities, the principles are the same and appropriate adaptations to available soil and cropping systems could be derived directly.

Table 21-a -- Projected crop distribution with irrigation - Arenac County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - -	Acres	(thousands)	- - - -	- - - -	- -	Acre inches/year	Acre in/yr (thousands)
F	11	90	10	6.1	2.0	0	2.0	0	12.5	127
G	28	44	12	7.4	2.5	0	2.5	0	12.5	155
H	30	81	24	8.5	9.8	2.4	3.7	0	17.4	425
M	4.5	81	3.7	.9	1.8	.7	.2	0	18.2	67
V	30	79	24	9.4	9.4	2.4	2.4	0	27.2	642
W	2	73	1.5					1.5	35	53
X	8	0	0							
Total	113.5		76	32	26	5.5	11	1.5		1,470

Table 21-b -- Projected crop distribution with irrigation - Bay County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - -	Acres (thousands)	- - - -	- - - -	- - - -	- - -	Acre inches/year	Acre in/yr (thousands)
F	.8	90	.7	.4	.1	0	.1	0	12.5	8
G	3.2	44	1.4	.8	.3	0	.3	0	12.5	17
H	61	81	49	17	20	4.9	7.4	0	18.8	928
J	35	81	28	9.8	11	2.8	4.2	0	18.1	509
M	23	81	19	4.7	9.2	3.8	.9	0	22.5	422
T	15	0	0							
V	4.4	65	2.9					2.9	28.5	82
Total	142		101	33	41	12	13	2.9		1,967

Table 21-c -- Projected crop distribution with irrigation - Clinton County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application: Rate/acre	Water Application: Total
	Acres (thousands)	%	- - - - - - - -	Acres (thousands)	- - - - - - - -				Acre inches/year	Acre in/yr (thousands)
H	97	81	78	27	31	7.8	12		18.2	1,428
K	104	50	52	31	10	5.2	5.2		22.5	1,167
L	2	58	1.1	.4	.4	.1	.2		23.4	27
M	26	81	21	5.3	11	4.3	1.1		25	536
R	21	24	5	3.8	.5	.5	.2		37.8	193
X	6.6	0	0	0	0	0	0			
Total	256.6		158	68	53	18	19			3,351

Table 21-d -- Projected crop distribution with irrigation - East one-half of Eaton County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - -	- Acres	(thousands)	- - - - - - -			Acre inches/year	Acre in/yr (thousands)
K	85	50	42	25	8.4	4.2	4.2	0	27.4	1,155
L	13	58	7.7	2.7	2.7	.8	1.5	0	23.8	183
N	1.8	46	.8	.4	.1	.1	.2	0	40	32
Total	217.8		51	28	11	5.1	6.0	0		1,371

Table 21-e -- Projected crop distribution with irrigation - Genesee County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - - Acres (thousands) - - - - - - - - - -						Acre inches/year	Acre in/yr (thousands)
F	17	90	15	9.1	3.0	0	3.0	0	15	227
K	46	50	23	14	4.5	2.3	2.3	0	25.9	590
L	60	58	35	12	12	3.5	6.9	0	23.7	825
M	9.6	88	8.5	3.4	3.4	1.7	0	0	20.6	175
R	4.0	23.4	1.0	.7	.1	.1	.05	0	35	33
Q	14	0	0							
Total	301.6		82	39	23	7.5	12	0		1,851

Table 21-f -- Projected crop distribution with irrigation - Gladwin County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - -	Acres (thousands)	- - - - - - - -				Acre inches/year	Acre in/yr (thousands)
G	37	44	16	9.7	3.2	0	3.2	0	17.2	279
M	21	81	17	4.2	8.4	3.4	.8	0	22.1	372
V	4.6	65	3.0					3.0	36.5	109
W	5.2	50	2.6					2.6	33.8	86
Total			39	14	12	3.4	4.1	5.5		846

Table 21-g -- Projected crop distribution with irrigation - Gratiot County, 1985

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - -	- Acres	(thousands)	- - - -	- - - -		Acre inches/year	Acre in/yr (thousands)
F	3.1	90	2.8	1.7	.6	0	.6	0	12.5	35
H	104	81	84	29	34	8.4	13	0	19.4	1,632
K	104	50	52	31	10	5.2	5.2	0	25.4	1,313
M	46	81	38	9.4	19	7.5	1.9	0	19.0	716
Q	17	0	0							
Total	274.1		176	72	63	21	20	0		3,695

Table 21-h -- Projected crop distribution with irrigation - Hillsdale County, 1985

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - - -	Acres (thousands)	- - - - - - - - -				Acre inches/year	Acre in/yr (thousands)
F	33	90	30	18	6.0	0	6.0	0	10.0	291
G	10	44	4.4	2.7	.9	0	.9	0	8.75	39
K	104	50	52	31	10	5.2	5.2	0	25.4	1,309
N	123	46	56	31	5.6	5.6	14	0	38.4	2,160
R	.2	24	.05	.05	0	0	0	0	40	2
Total	270.2		142	82	23	11	26			3,800

Table 21-i -- Projected crop distribution with irrigation - Huron County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - -	- Acres	(thousands)	- - - -	- - - -	- - -	Acre inches/year	Acre in/yr (thousands)
H	1.8	81	1.5	.5	.5	.1	.2	0	18.8	27
I	235	89	210	74	84	21	32	0	15.0	3,155
K	26	50	13	7.7	2.6	1.3	1.3	0	24.4	314
M	59	81	48	12	24	9.6	2.4	0	21.2	1,018
R	51	24	12	9.1	1.2	1.2	.6	0	40.0	486
T	8.8	0	0							
Total	381.6		285	103	113	33	36	0		5,000

Table 21-j -- Projected crop distribution with irrigation - Ingham County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - - -	Acres	(thousands)	- - - - - - -			Acre inches/year	Acre in/yr (thousands)
K	56	50	28	17	5.5	2.8	2.8	0	27.4	576
L	81	58	47	16	16	4.7	9.4	0	25.2	1,182
N	31	46	15	8.2	1.5	1.5	3.7	0	38.5	574
O	33	38	12	7.5	2.5	1.2	1.2	0	37.8	470
R	7.4	24	1.7	1.3	.2	.2	.1	0	37.0	65
X	.3	0	0							
Total	208.7		104	50	26	10	17	0		2,867

Table 21-k -- Projected crop distribution with irrigation - Jackson County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - - -	Acres	(thousands)	- - - -	- - - -	-	Acre inches/year	Acre in/yr (thousands)
K	1.8	50	.9	.5	.2	.1	.1	0	27.4	25
N	117	46	54	30	5.4	5.4	14	0	38.5	2,074
O	6.5	38	2.5	1.5	.5	.2	.2	0	35.8	89
P	39	57	22	12	2.2	2.2	5.6	0	39.8	887
R	5.5	24	1.3	1.0	.1	.1	.1	0	40	52
X	14	0	0							
Total	183.8		81	45	8.4	8.1	19	0		3,237

Table 21-1 -- Projected crop distribution with irrigation - Lapeer County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - -	- Acres	(thousands)	- - - -	- - - -		Acre inches/year	Acre in/yr (thousands)
D	12	0	0							
K	40	50	20	12	4.0	2.0	2.0	0	21.9	440
L	56	58	32	11	11	6.5	3.2	0	24.6	793
O	36	38	14	8.3	2.8	1.4	1.4	0	34.8	479
R	21	24	4.9	3.7	.5	.5	.2	0	38.5	189
Q	11	0	0							
S	12	91	11	8.3	1.1	1.1	.6	0	40	442
X	12	0	0							
Total	200.0		82	44	20	11	7.4			2,343

Table 21-m -- Projected crop distribution with irrigation -- Lenawee County, 1985

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - -	- - Acres	(thousands)	- - - -	- - - -	- -	Acre inches/year	Acre in/yr (thousands)
F	106	90	96	58	19	0	19	0	7.5	719
G	112	44	50	30	10	0	10	0	8.1	405
K	7	50	3.5	2.1	.7	.3	.3	0	31.4	109
M	57	88	50	20	20	0	10	0	25.6	1,289
P	.5	57	.3	.2	.03	.03	.07	0	39.8	11
Q	17	0	0							
R	26	24	6.2	4.7	.6	.6	.3	0	40	248
S	15	91	14	10	1.4	1.4	.7	0	25.6	355
Total	340.5		220	125	52	2.4	41	0		3,137

Table 21-n -- Projected crop distribution with irrigation - Livingston County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - -	- - - - Acres	(thousands)	- - - -	- - - -	- - - -	Acre inches/year	Acre in/yr (thousands)
K	97	50	48	29	9.6	4.8	4.8	0	25.9	1,244
L	49	58	28	9.9	9.9	5.7	2.8	0	25.2	714
O	8.2	38	3.2	1.9	.6	.3	.3	0	37.8	119
P	18	57	10	5.7	1.0	1.0	2.6	0	37	385
Q	.8	0	0							
R	18	24	4.3	3.2	.4	.4	.2	0	38.5	167
Total	191.0		94	50	22	12	11			2,629

Table 21-o -- Projected crop distribution with irrigation - Macomb County, 1985.

Crop Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - -	- - - Acres	(thousands) - - -	- - - - -	- - - - -	- - -	Acre inches/year	Acre in/yr (thousands)
D	7.4	0								
F	17	90	15	9.1	3.0	0	3.0	0	3.8	57
K	9.6	50	4.8	2.9	1.0	.5	.5	0	26.1	125
L	38	58	22	7.8	7.8	4.4	2.2	0	26.9	596
M	32	88	29	11	11	5.7	0	0	20.0	575
O	4.2	38	1.6	1.0	.3	.2	.2	0	34.5	55
P	4.5	57	2.6	1.4	.3	.3	.6	0	37.5	97
Total	112.7		75	34	24	11	6.5	0		1,504

Table 21-p -- Projected crop distribution with irrigation - Midland County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - -	- Acres	(thousands)	- - -	- - - -	- -	Acre inches/year	Acre in/yr (thousands)
F	20	90	18	11	3.5	0	3.5	0	12.5	221
H	20	81	16	5.5	6.3	1.6	2.4	0	18.8	298
M	36	81	29	7.3	15	5.8	1.5	0	22.1	642
W	21	50	10					10	33.8	344
Total	97		73	23	24	7.4	7.4	10		1,504

Table 21-q -- Projected crop distribution with irrigation - Monroe County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - -	- - Acres	(thousands) - -	- - - - - - - -			Acre inches/year	Acre in/yr (thousands)
D	38	0	0							
F	15	90	13	7.9	2.6	0	2.6	0	10.0	132
M	86	88	76	30	30	15	0	0	22.5	1,707
U	55	79	44	17	17	4.4	4.4	0	34.0	1,484
Total	194		133	56	50	20	7.0	0		3,323

Table 21-r -- Projected crop distribution with irrigation - Oakland County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - - -	Acres	(thousands)	- - - - - - - - -			Acre inches/year	Acre in/yr (thousands)
E	6.6	0	0							
K	40	50	20	12	4.0	2.0	2.0	0	25.9	512
M	1.1	88	1.0	.4	.4	.2	0	0	20.0	19
O	36	38	14	8.1	2.7	1.4	1.4	0	38.8	526
P	12	57	6.7	3.7	.7	.7	1.7	0	37.0	249
R	11	24	2.6	1.9	.3	.3	.1	0	38.5	99
U	.4	79	.3	.1	.1	.04	.04	0	37.5	13
Total	107.1		44	26	8.1	4.5	5.2	0		1,418

Table 21-s -- Projected crop distribution with irrigation - Saginaw County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - - -	Acres	(thousands)	- - - - - - - - -			Acre inches/year	Acre in/yr (thousands)
D	29	0	0							
J	12	81	9.7	3.4	3.9	1.0	1.5	0	18.1	176
H	53	81	43	15	17	4.3	6.5	0	18.8	815
L	22	58	13	4.5	4.5	1.3	2.6	0	22.5	291
M	169	81	138	34	69	28	6.9	0	18.6	2,559
Total	285		204	58	95	34	17	0		3,842

Table 21-t -- Projected crop distribution with irrigation - Sanilac County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - -	Acres (thousands)					Acre inches/year	Acre in/yr (thousands)
I	4.0	89	3.6	1.3	1.4	.4	.5	0	12.5	45
K	64	50	32	19	6.4	3.2	3.2	0	24.4	776
L	231	58	134	47	47	27	13	0	25.5	3,405
M	74	81	60	15	30	12	3.0	0	22.5	1,343
R	24	24	5.7	4.2	.6	.6	.3	0	39.2	222
T	16	0	0							
Q	36	0	0							
X	18	0	0							
Total	467		234	86	85	43	20	0		5,790

Table 21-u -- Projected crop distribution with irrigation - Shiawassee County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - -	- - - -	Acres	(thousands)	- - - -	- - - -	Acre inches/year	Acre in/yr (thousands)
K	65	50	32	19	6.5	3.2	3.2	0	22.5	728
L	121	58	70	25	25	7.0	14	0	22.5	1,566
R	35	24	8.2	6.2	.8	.8	.4	0	37.8	310
X	9	0	0							
Total	230		110	50	32	11	18	0		2,605

Table 21-v -- Projected crop distribution with irrigation - St. Clair County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application: Rate/acre	Water Application: Total
	Acres (thousands)	%	- - - - - - - -	- - Acres	(thousands)	- -	- - - -	- -	Acre inches/year	Acre in/yr (thousands)
D	68	0	0							
K	9.6	50	4.8	2.9	1.0	.5	.5	0	15.6	74
L	120	58	69	24	24	6.9	13.9	0	20.6	1,428
M	7.2	88	6.4	2.5	2.5	1.3	0	0	22.5	143
T	6.9	0	0							
U	11.5	79	9.1	3.7	3.7	.9	.9	0	27.0	246
V	1.8	65	1.1					1.1	33.8	38
X	17	0	0							
Total	242.0		94	35	33	10	16	1.1		1,930

Table 21-w -- Projected crop distribution with irrigation - Tuscola County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - -	- -	Acres (thousands)	- -	- - - -	- - - -	Acre inches/year	Acre in/yr (thousands)
H	108	81	88	31	35	8.8	13	0	18.8	1,649
I	1.6	89	1.4	.5	.6	.1	.2	0	12.5	18
J	30	81	24	8.4	9.6	2.4	3.6	0	18.1	435
K	59	50	30	18	6.2	3.1	3.1	0	21.9	657
M	58	81	47	12	24	9.4	2.4	0	22.5	1,060
R	13	24	3.0	2.2	.3	.3	.2	0	32.5	97
T	0									
V	23	65	15					15	37.5	556
Total	296.6		209	72	75	24	23	15		4,472

Table 21-x -- Projected crop distribution with irrigation - Washtenaw County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - - -	Acres (thousands)	- - - - - - - - -				Acre inches/year	Acre in/yr (thousands)
E	10	0	0							
G	27	44	12	7.2	2.4	0	2.4	0	8.1	98
K	87	50	43	26	8.7	4.3	4.3	0	25.9	1,126
M	20	88	18	7.2	7.2	3.6	0	0	20	361
P	14	57	7.0	4.4	.8	.8	2.0	0	39.8	315
Q	4.4	0	0							
R	60	24	14	11	1.4	1.4	.7	0	34.5	493
S	14	91	12	9.3	1.2	1.2	.6	0	40.0	496
U	8.3	79	6.5	2.6	2.6	.7	.7	0	34.0	222
Total	244.7		115	68	24	12	11			3,111

Table 21-y -- Projected crop distribution with irrigation -- Wayne County, 1985.

Soil Assoc.	Agric. Acres	Percent Usable	Usable Acres	Corn	Beans	Small Grains	Hay Pasture	Trees	Water Application Rate/acre	Water Application Total
	Acres (thousands)	%	- - - - - - - -	Acres (thousands)	- - - - - - - -				Acre inches/year	Acre in/yr (thousands)
D	8.9	0	0							
E	2.4	0	0							
K	.8	50	.4	.2	.2	.08	.08	0	25.9	9.7
M	9.7	88	8.6	3.4	3.4	1.7	0	0	20.0	172
R	3.2	24	.8	.6	.08	.08	.04	0	38.5	29
S	3.0	91	2.7	2.1	.3	.3	.1	0	40.0	109
T	0									
U	12	79	9.3	3.7	3.7	.9	.9	0	34.0	315
Total	40.0		22	10	7.6	3.1	1.2	0		635

LITERATURE CITED

Beeson, K. C. 1941. The mineral composition of crops with particular reference to the soils in which they are grown. U.S.D.A. Misc. Pub'n No. 369.

Cook, R. L. and C. E. Millar. 1953. Plant nutrient deficiencies. Spec. Bul. 353, Mich. Agr. Exp. Stat., MSU.

Christenson, D. R., R. E. Lucas and E. C. Doll. 1972. Fertilizer recommendations for Michigan vegetables and field crops. Ext. Bul. E-550, Coop. Ext. Service, MSU.

CRREL. 1972. Wastewater management by disposal on land. Corps of Engineers, U. S. Army, Cold Regions Research and Engineering Laboratory. Hanover, New Hampshire.

Ellis, Boyd G. 1973. The soil as a chemical filter. Proc. of symposium on "Recycling treated municipal wastewater and sludge through forest and crop land." Penn. State Univ.

Impact of waste water on soils. 1972. Tech. Rept. No. 30, Institute of water research. MSU.

Michigan Crop Reporting Service. 1970. Michigan agricultural statistics, July 1970. Michigan Department of Agriculture.

Michigan State Conservation Needs Inventory Committee. 1969. Michigan conservation needs inventory 1968. U. S. Soil Conservation Service.

Michigan State University. 1973. Highlights and summary of Project '80 & 5. Mich. State Univ. Agr. Expt. Sta. Res. Report 180.

Miller, D.F. 1968. Composition of cereal grains and forages. Publication 585. Nat. Acad. of Sci. -- Nat. Res. Council, Washington, D.C.

Morrison, F. B. 1959. Feeds and Feeding. The Morrison Publ. Co., Clinton, Iowa.

Piper, Curtis D. 1967. The influence of deep mixing a Kalamazoo sandy loam on several physical soil factors and corn root development. PhD. Thesis, MSU.

Romaine, J. D. 1965. Consider plant food content. Better Crops. American Potash Institute, Inc., Washington, D.C.

Soil Testing and Plant Analysis. 1967. Soil testing. Soil Sci. Soc. Amer. Special Pub. No. 2, Part I, Soil Sci. Soc. Amer., Inc., Madison, Wisconsin.

Soil Testing and Plant Analysis. 1967. Plant analysis. Soil Sci. Soc. Amer. Special Pub. No. 2, Part II, Soil Sci. Soc. Amer., Inc., Madison, Wisconsin

U. S. Bureau of the Census. 1972. Census of agriculture, 1969, Volume I. Area reports; Part 13. Michigan; Section 2. County data. U. S. Government Printing Office, Washington, D.C.

WASTEWATER IRRIGATION USING PRIVATELY OWNED FARMLAND IN SOUTHEASTERN MICHIGAN

Phase IV Report

JULY 23, 1973

Contract No: DACW 35-72-C-0028

Prepared for
DETROIT DISTRICT OF
THE U.S. ARMY CORPS OF ENGINEERS

by
DOW ENGINEERING, INC.
MIDLAND, MICHIGAN 48640

ABSTRACT

A conceptual design utilizing privately owned farm land in lieu of publicly owned land was developed for land treatment of Southeastern Michigan's wastewater. Private farmers retain ownership and management of the farm land. They contract for a prescribed irrigation schedule determined by the soil conditions and their choice of crops. The Southeastern Michigan area was subdivided into 17 treatment zones according to soil associations. Capital costs for the wastewater treatment zones range from \$3,400 to \$6,900 per million gallons with annual costs ranging from \$360 to \$695 per million gallons of water treated. Costs do not include sewage collection and transmission treatment, disinfection, winter storage, and sludge disposal. Land treatment using privately owned farm land has several benefits and detriments for farmers and society.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SECTION I

INTRODUCTION

Land treatment is one of several alternatives being considered for the Southeastern Michigan Wastewater Management Program. In this program, land treatment means wastewater is collected, treated, disinfected, and finally irrigated onto agricultural lands. The soil, growing plants, and soil microorganisms provide further treatment by removing potential pollutants from the wastewater. The resulting water is then collected in underdrains for reuse and/or discharge into nearby streams or lakes.

Earlier, a land treatment plan was developed for the Southeastern Michigan area. This plan assumed public acquisition of all agricultural land within the irrigation site, relocation of farm families living within the irrigation site, and a specialized farm management program to achieve wastewater renovation.

A report entitled Irrigation and Collection Facilities for Southeastern Michigan Wastewater Management Program (3) gives designs, costs, and an agricultural program for the above. Hereafter, this report is referred to as the Phase I-Phase II Report. A companion report entitled Impact of Wastewater on Soils (4) was prepared for the CORPS by the Institute of Water Research-Michigan State University.

In various communities in Southwestern U S. and other countries, private farmers receive wastewater under contract and use this water to irrigate their crops. This practice appears to be a viable alternative to the public ownership of the agricultural land considered in the Phase I-Phase II Report. Private ownership would allow farmers to continue their normal operation while renovating the wastewater produced in Southeastern Michigan urban centers.

Hence, the CORPS initiated Phase III and Phase IV studies to develop concepts and costs for land treatment of wastewater using privately owned farm land. Total time allowed for both phases was 55 calendar days. The Phase III study was largely conducted by crop and soil scientists at Michigan State University and is published in a report entitled Land Treatment of Wastewater in Southeastern Michigan (5). The Phase III Report contains data on (i) soils, (ii) land use and crops, and (iii) projected application of wastewater in 25 Southeastern Michigan counties. The Phase III study serves as a basis for the Phase IV study.

The purpose of this Phase IV study is to (i) describe conceptual designs for irrigating wastewater onto privately owned farm land, (ii) develop cost estimates for applying wastewater to farm land within the 25 Southeastern Michigan counties, and (iii) highlight possible benefits and detriments accrued from land treatment of wastewater.

SECTION II

WASTEWATER TREATMENT ZONES

Extensive land area is required to treat the wastewater produced within Southeastern Michigan. The 1990 projected wastewater flow is 2.7 billion gallons per day or about 36.3 million acre-inches* per year. The usable agricultural land considered in the Phase III Report (5) will treat about 67.5 million acre-inches per year. Thus, land areas to receive the wastewater must be identified so that conceptual designs can be developed. Many possible methods exist for identifying these land areas or wastewater treatment zones. Perhaps, the most meaningful method is based on soil considerations. Hence, soil associations are used as building blocks for development of wastewater treatment zones. The Phase III Report (5) provides various data by soil association within each county. Also, major soil associations are delineated on a map of the 25 Southeastern Michigan counties in Figure 1 - Phase III Report.

Most soils within Southeastern Michigan are capable of wastewater renovation. The phosphorus adsorption and/or hydraulic characteristics of the soils limit the quantity of wastewater which can be applied

*An acre-inch of water is equivalent to about 27,150 gallons.

and renovated. Further, the agricultural crop grown on the soils influences the quantity and time of wastewater applications. The Phase III Report (5) summarizes application rates (acre-inches per year) based on soil and crop considerations for each soil association within each county. For example, the area represented by Soil Association K in Washtenaw County can receive a total of 1,126,000 acre-inches of wastewater per year (Table 21x - Phase III Report) for an average of 26 inches per year on the 43,000 acres of usable cropland.

Only a portion of the total acreage within a soil association area is cropland useful for wastewater treatment. Other lands include urban, forest, and agricultural not useful for wastewater treatment. Land uses for each soil association area within each county were tabulated in the Phase III Report (5). For example, the area represented by Soil Association K in Washtenaw County contains 159,000 acres with 43,000 acres of cropland useful for wastewater treatment (Table 4x - Phase III Report).

Wastewater can be applied to any soil association area containing some usable cropland. Ideally, the more desirable areas possess (i) a high percentage of usable cropland and (ii) soils and crops permitting high wastewater application rates. Thus, high wastewater quantities can be applied to a small total land area. An indication for this is the average application rate for the entire soil association area. This average rate is computed by dividing the total

wastewater application in acre-inches per year (Tables 21a - 21y - Phase III Report) by the total acres contained in the soil association area (Tables 4a - 4y - Phase III Report). The area represented by Soil Association K in Washtenaw County has an average wastewater application of 7.1 inches per year (1,126,000 acre-inches per year ÷ 159,000 acres). Average application rates for the soil association areas within each county are shown in Table I. Rates range from 0 to about 20 inches per year.

Adjacent soil association areas often possess very similar average application rates. Hence, these similar areas were grouped into zones, some of which can be used for wastewater treatment (Figure 1). The Southeastern Michigan area is divided into 17 zones. Much of Zones II, III, IV, VI, X, XIII, and XVI can receive an average rate of more than eight inches per year. Generally, Zones I, VII, IX, XI, XII, and XIV can receive less than eight inches per year. Certain large areas within Zone VII and XII and the Zones V, VIII, XV, and XVII, are unsuitable for any wastewater application because of soil considerations or large urban areas.

Soil association areas were grouped into zones largely for convenience in identifying costs for specific areas within Southeastern Michigan. Costs will be identified by counties within each zone. Hence, an entire zone or county subdivisions of the zones can be considered for wastewater application.

Table I

Average Wastewater Application Rate for Soil Association Areas

County	Soil Assoc.	Avg. Rate In/Yr
Arenac	F	8.5
	G	3.6
	H	9.9
	M	9.6
	V	7.6
	W	2.5
	X	0.0
Bay	F	8.0
	G	2.4
	H	11.4
	J	6.6
	M	6.4
	T	0.0
	V	0.7
Clinton	H	10.3
	K	7.8
	L	13.5
	M	16.2
	R	5.8
	X	0.0

County	Soil Assoc.	Avg. Rate In/Yr
Genesee	F	9.5
	K	4.5
	L	4.8
	M	7.3
	R	2.1
	Q	0.0
Gladwin	G	4.8
	M	2.7
	V	4.7
	W	0.8
Gratiot	F	8.7
	H	11.0
	K	10.1
	M	12.3
	Q	0.0
Hillsdale	F	6.3
	G	3.2
	K	8.3
	N	12.9
	R	1.0

County	Soil Assoc.	Avg. Rate In/Yr
Ingham	K	5.2
	L	13.1
	N	12.2
	O	7.2
	R	3.1
	X	0.0
Jackson	K	6.2
	N	7.9
	O	6.8
	P	8.0
	R	2.4
	X	0.0
Lapeer	D	0.0
	K	4.4
	L	8.5
	O	6.0
	R	3.2
	Q	0.0
	S	20.1
	X	0.0

Table I (Cont.)

County	Soil Assoc.	Avg. Rate In/Yr	County	Soil Assoc.	Avg. Rate In/Yr	County	Soil Assoc.	Avg. Rate In/Yr
Eaton	K	7.2	Huron	H	13.5	Lenawee	F	5.8
	L	10.2		I	10.7		G	2.3
	N	6.4		K	6.7		K	10.9
				M	11.2		M	19.2
Living-	K	7.7		R	7.1		P	11.0
ston	L	10.2		T	0.0		Q	0.0
	O	10.8					R	4.3
	P	11.7	Saginaw	D	0.0		S	18.7
	Q	0.0		J	3.7			
	R	1.8		H	9.2	Tuscola	H	12.2
				L	10.4		I	9.0
Macomb	D	0.0		M	8.3		J	11.8
	F	2.4					K	6.0
	K	5.2	Sanilac	I	11.2		M	7.3
	L	10.1		K	9.7		R	4.6
	M	3.5		L	11.1		T	0.0
	O	4.6		M	13.7		V	9.8
	P	5.4		R	6.5			
	U	---		T	0.0	Washtenaw	E	0.0
				Q	0.0		G	1.4
Midland	F	9.6		X	0.0		K	7.1
	H	9.9					M	10.6
	M	4.5	Shiawassee	K	7.8		P	13.7
	W	2.5		L	9.1		Q	0.0
				R	4.5		R	6.2
				X	0.0		S	14.6
							U	20.2

Table I (Cont.)

County	Soil Assoc.	Avg. Rate In/Yr	County	Soil Assoc.	Avg. Rate In/Yr	County	Soil Assoc.	Avg. Rate In/Yr
Monroe	D	0.0	St. Clair	D	0.0	Wayne	D	0.0
	F	2.4		K	4.6		E	0.0
	M	12.9		L	7.9		K	9.7
	U	13.4		M	15.9		M	0.9
				T	0.0		R	3.6
Oakland	E	0.0		U	10.7		S	9.1
	K	3.6		V	1.1		T	0.0
	M	0.4		X	0.0		U	8.1
	O	3.7						
	P	2.5						
	R	1.8						
	U	0.6						

Figure 1

Wastewater Treatment Zones
and Soil Associations for
Southeastern Michigan

From the Phase III Report (5), land use, cropping, and wastewater application data are retabulated for the zones. These data are contained in Tables II and III.

Table II

LAND USE WITHIN ZONES

	ACRES (THOUSANDS)				
	TOTAL LAND	FOREST	URBAN	OTHER	AGRICULTURE
ZONE 1					
ARENAC	215.7	83.7	14.4	17.1	99.6
BAY	84.0	42.0	3.5	7.8	30.6
GLADWIN	322.0	225.8	6.7	22.5	66.9
MIDLAND	258.5	155.8	25.8	25.8	50.8
TOTAL	880.2	507.3	50.4	73.2	247.9
ZONE 2					
HURON	500.0	82.3	21.4	24.9	371.1
LAPEER	5.0	1.2	1.0	0.7	2.0
SANILAC	216.0	29.5	10.6	10.6	165.3
ST. CLAIR	25.0	5.5	0.4	2.2	16.8
TUSCOLA	289.0	83.3	20.0	51.9	133.5
TOTAL	1035.0	201.8	53.4	90.3	688.7
ZONE 3					
CLINTON	152.9	15.2	15.2	15.2	107.0
GRATIOT	300.0	31.1	29.8	15.0	224.1
MIDLAND	15.0	2.2	2.2	0.7	9.7
TOTAL	467.9	48.5	47.2	30.9	340.8
ZONE 4					
ARENAC	19.3	1.5	1.7	1.7	14.2
BAY	159.0	12.1	38.9	11.8	96.0
CLINTON	33.0	1.6	3.3	1.6	26.4
GENESEE	225.1	33.1	79.7	33.7	78.3
GRATIOT	62.0	6.4	3.0	3.1	49.4
HURON	2.0	0.1	0.0	0.1	1.8
LAPEER	5.0	1.2	1.0	0.7	2.0
MIDLAND	59.4	16.2	4.3	3.9	34.5
SAGINAW	521.0	87.7	92.8	54.5	285.6
SHIAWASSEE	147.6	13.9	14.0	14.2	105.3
TUSCOLA	222.0	25.9	9.9	24.0	161.8
TOTAL	1455.4	199.7	248.6	149.3	855.3
ZONE 5					
GENESEE	45.0	6.8	18.0	6.8	13.5
LAPEER	44.0	6.6	5.5	7.7	24.2
TOTAL	89.0	13.4	23.5	14.5	37.7
ZONE 6					
LAPEER	125.1	23.3	11.0	18.7	71.9
MACOMB	83.0	11.9	14.2	8.9	47.9
SANILAC	319.5	47.3	15.9	15.9	240.2
ST. CLAIR	194.9	19.4	27.2	19.4	128.9
TOTAL	722.5	101.9	68.3	62.9	488.9

Table II (Cont.)

LAND USE WITHIN ZONES

ACRES (THOUSANDS)

	TOTAL LAND	FOREST	URBAN	OTHER	AGRICULTURE
ZONE 7					
MACOMB	11.1	2.2	2.2	2.2	4.4
SANILAC	58.5	5.8	4.4	2.8	45.2
ST. CLAIR	203.0	38.5	55.3	22.0	87.0
TOTAL	272.6	46.5	61.9	27.0	136.6
ZONE 8					
SANILAC	21.0	2.1	1.8	1.1	16.1
ST. CLAIR	23.0	6.9	6.9	2.3	6.9
TOTAL	44.0	9.0	8.7	3.4	23.0
ZONE 9					
CLINTON	180.1	21.1	17.2	17.8	121.8
EATON	178.0	51.6	16.6	11.8	98.0
INGHAM	197.0	33.6	50.4	17.4	95.3
JACKSON	17.0	1.6	1.5	5.5	8.3
LIVINGSTON	5.5	0.8	0.3	0.1	4.1
SHIAWASSEE	157.3	33.9	15.7	11.2	96.3
TOTAL	734.9	142.6	101.7	63.8	423.8
ZONE 10					
GENESEE	24.0	4.8	1.2	1.2	16.8
INGHAM	111.0	13.2	6.2	10.5	81.1
LIVINGSTON	70.0	10.5	3.5	7.0	49.0
SHIAWASSEE	34.4	3.4	3.4	3.4	24.0
TOTAL	239.4	31.9	14.3	22.1	170.9
ZONE 11					
GENESEE	117.9	17.6	41.2	17.6	41.2
LAPEER	201.8	66.0	26.3	27.2	81.9
LIVINGSTON	194.0	43.7	17.7	17.7	114.7
OAKLAND	49.7	7.9	19.8	7.9	13.9
SHIAWASSEE	4.6	0.6	0.4	0.2	3.2
TOTAL	568.0	135.8	105.4	70.6	254.9
ZONE 12					
LAPEER	40.0	12.0	4.0	6.0	18.0
LIVINGSTON	97.5	32.7	18.6	22.8	23.1
MACOMB	107.8	16.5	20.4	9.7	60.9
MONROE	61.0	1.8	14.0	7.3	37.8
OAKLAND	419.0	98.6	175.0	66.2	79.1
WAYNE	97.0	10.9	64.3	9.7	12.1
TOTAL	822.3	172.5	296.3	121.7	231.0

Table II (Cont.)

LAND USE WITHIN ZONES

ACRES (THOUSANDS)

	TOTAL LAND	FOREST	URBAN	OTHER	AGRICULTURE
ZONE 13					
EATON	25.0	0.6	2.2	0.4	1.8
HILLSDALE	325.0	56.0	18.1	24.6	226.2
INGHAM	47.0	7.0	4.7	4.7	30.5
JACKSON	429.0	90.8	70.0	92.1	175.7
LENAWEE	10.0	1.5	1.0	0.5	7.0
TOTAL	836.0	155.9	96.0	122.3	441.2
ZONE 14					
HILLSDALE	59.0	9.1	1.5	5.1	43.3
LENAWEE	207.0	23.4	28.8	19.0	135.4
OAKLAND	21.3	3.4	8.5	3.4	5.9
WASHTENAW	313.0	59.9	36.5	34.7	181.6
WAYNE	1.0	0.2	0.0	0.0	0.7
TOTAL	601.3	96.0	75.3	62.2	366.9
ZONE 15					
LENAWEE	29.0	1.4	7.2	2.9	17.4
OAKLAND	33.0	3.3	18.1	4.9	6.6
WASHTENAW	45.0	12.3	12.4	5.6	14.6
WAYNE	8.0	2.0	2.4	1.2	2.4
TOTAL	115.0	19.0	40.1	14.6	41.0
ZONE 16					
LENAWEE	236.0	20.0	21.5	11.9	181.9
MONROE	297.0	31.4	55.2	55.0	155.4
WASHTENAW	96.0	17.7	20.0	9.0	49.0
WAYNE	280.0	27.3	197.1	31.1	24.4
TOTAL	909.0	96.4	293.8	107.0	410.7
ZONE 17					
BAY	43.0	12.9	8.6	6.4	15.0
HURON	22.0	6.6	4.4	2.2	8.8
TUSCOLA	10.0	3.0	0.0	7.0	0.0
TOTAL	75.0	22.5	13.0	15.6	23.8

Table III

PROJECTED CROP DISTRIBUTION WITH IRRIGATION - YEAR 1985

	AGRICULTURE LAND	USABLE AGRICULTURE LAND	CORN	BEANS	SMALL GRAINS	HAY PASTURE	TREES	WASTEWATER APPLICATION AVERAGE IN/YR	WASTEWATER APPLICATION TOTAL ACRE-IN/YR (THOUSANDS)
	ACRES (THOUSANDS)								
ZONE 1									
ARENAC	99.5	62.8	25.3	22.5	5.2	8.4	1.5	20.6	1299.5
BAY	30.6	23.3	5.5	9.5	3.8	1.2	2.9	19.1	447.2
GLADWIN	67.8	38.6	13.9	11.6	3.4	4.0	5.6	21.9	846.0
MIDLAND	51.6	34.6	6.2	12.7	4.9	1.2	10.0	25.7	889.7
TOTAL	249.5	159.3	50.9	56.3	17.3	14.8	20.0	21.8	3482.4
ZONE 2									
HURON	371.0	283.0	102.8	111.8	33.1	36.3	0.0	17.5	4972.0
LAPEER	2.0	1.0	0.6	0.2	0.1	0.1	0.0	22.0	22.0
SANILAC	166.0	101.3	39.5	38.4	16.2	7.0	0.0	23.5	2386.0
ST. CLAIR	16.8	11.2	5.4	3.5	1.8	0.5	0.0	19.3	217.0
TUSCOLA	134.0	85.0	29.1	26.0	10.7	5.2	15.0	24.7	2105.0
TOTAL	689.8	481.5	177.4	179.9	61.9	49.1	15.0	20.1	9702.0
ZONE 3									
CLINTON	107.4	83.2	30.1	32.0	8.3	12.5	0.0	18.5	1544.7
GRATIOT	225.0	136.0	60.0	44.0	13.6	18.2	0.0	21.6	2945.0
MIDLAND	10.0	8.0	2.7	3.1	0.8	1.2	0.0	18.6	149.0
TOTAL	342.4	227.2	92.8	79.1	22.7	31.9	0.0	20.4	4638.7
ZONE 4									
ARENAC	14.0	12.4	6.9	2.9	0.2	2.3	0.0	13.6	169.5
BAY	95.8	77.7	27.2	31.1	7.7	11.7	0.0	18.5	1445.0
CLINTON	26.0	21.0	5.3	11.0	4.3	1.1	0.0	25.5	536.0
GENESEE	78.2	46.8	17.5	15.9	5.5	7.1	0.0	23.3	1092.0
GRATIOT	49.1	40.8	11.1	19.6	7.5	2.5	0.0	18.4	751.0
HURON	1.8	1.5	0.5	0.5	0.1	0.2	0.0	18.0	27.0
LAPEER	2.0	1.0	0.6	0.2	0.1	0.1	0.0	22.0	22.0
MIDLAND	35.4	30.3	14.7	8.8	1.6	4.9	0.0	15.3	466.3
SAGINAW	285.0	203.7	56.9	94.4	34.6	17.5	0.0	18.8	3841.0
SHIAWASSEE	105.8	56.0	20.0	20.0	5.6	11.2	0.0	22.4	1257.6
TUSCOLA	162.6	124.4	44.0	49.7	13.3	17.2	0.0	19.2	2393.0
TOTAL	855.7	615.6	204.7	254.1	80.5	75.8	0.0	19.4	12000.4
ZONE 5									
GENESEE	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LAPEER	23.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	37.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table III (Cont.)

PROJECTED CROP DISTRIBUTION WITH IRRIGATION - YEAR 1985

	AGRICULTURE LAND	USABLE AGRICULTURE LAND	CORN	BEANS	SMALL GRAINS	HAY PASTURE	TREES	WASTEWATER APPLICATION AVERAGE IN/YR	WASTEWATER APPLICATION TOTAL ACRE-IN/YR (THOUSANDS)
	ACRES (THOUSANDS)								
ZONE 6									
LAPEER	72.0	34.0	12.2	11.4	6.7	3.4	0.0	24.6	837.0
MACOMB	47.6	26.8	10.7	8.8	4.9	2.7	0.0	26.9	721.0
SANILAC	240.0	134.0	47.0	47.0	27.0	13.0	0.0	25.4	3405.0
ST. CLAIR	131.0	65.5	22.8	22.8	6.5	13.2	0.0	20.7	1356.6
TOTAL	490.6	260.3	92.7	90.0	45.1	32.3	0.0	24.2	6319.6
ZONE 7									
MACOMB	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SANILAC	45.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ST. CLAIR	87.3	13.6	4.9	4.9	1.2	1.5	1.1	26.1	355.4
TOTAL	136.7	13.6	4.9	4.9	1.2	1.5	1.1	26.1	355.4
ZONE 8									
SANILAC	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ST. CLAIR	6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	22.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZONE 9									
CLINTON	123.2	52.9	32.1	9.9	5.2	5.0	0.0	24.0	1270.3
EATON	98.1	49.7	27.7	11.1	5.0	5.7	0.0	26.9	1338.0
INGHAM	96.7	41.7	25.8	8.2	4.2	4.1	0.0	26.6	1111.0
JACKSON	8.3	3.4	2.0	0.7	0.3	0.3	0.0	33.5	114.0
LIVINGSTON	4.1	1.6	0.9	0.3	0.1	0.1	0.0	37.1	59.5
SHIAWASSEE	96.7	38.6	24.2	6.9	3.8	3.4	0.0	25.9	1001.6
TOTAL	427.1	187.9	112.7	37.1	18.6	18.6	0.0	26.0	4894.4
ZONE 10									
GENESEE	17.0	15.0	9.1	3.0	0.0	3.0	0.0	15.1	227.0
INGHAM	81.0	47.0	16.0	16.0	4.7	9.4	0.0	25.1	1182.0
LIVINGSTON	49.0	28.0	9.9	9.9	5.7	2.8	0.0	25.5	714.0
SHIAWASSEE	24.2	14.0	5.0	5.0	1.4	2.8	0.0	22.4	314.4
TOTAL	171.2	104.0	40.0	33.9	11.8	18.0	0.0	23.4	2437.4
ZONE 11									
GENESEE	41.4	20.7	12.6	4.0	2.0	2.0	0.0	25.6	531.0
LAPEER	83.0	38.9	25.7	6.2	3.9	3.1	0.0	31.4	1222.5
LIVINGSTON	115.0	58.0	34.7	10.6	5.8	7.4	0.0	28.0	1629.0
OAKLAND	14.0	7.0	4.2	1.4	0.7	0.7	0.0	25.6	179.2
SHIAWASSEE	3.2	1.6	0.9	0.3	0.1	0.1	0.0	22.7	36.4
TOTAL	256.6	126.2	78.1	22.5	12.5	13.3	0.0	28.5	3598.1

Table III (Cont.)

PROJECTED CROP DISTRIBUTION WITH IRRIGATION - YEAR 1985

	AGRICULTURE LAND	USABLE AGRICULTURE LAND	CORN	BEANS	SMALL GRAINS	HAY PASTURE	TREES	WASTEWATER APPLICATION AVERAGE IN/YR	WASTEWATER APPLICATION TOTAL ACRE-IN/YR (THOUSANDS)
	ACRES (THOUSANDS)								
ZONE 12									
LAPEER	18.0	7.0	4.1	1.4	0.7	0.7	0.0	34.2	239.5
LIVINGSTON	22.9	5.9	4.1	0.7	0.5	0.3	0.0	38.3	226.5
MACOMB	60.6	48.2	22.5	14.6	6.2	3.8	0.0	16.2	784.0
MONROE	38.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OAKLAND	80.5	34.6	20.2	6.2	3.6	4.2	0.0	33.5	1162.0
WAYNE	12.1	0.8	0.6	0.0	0.0	0.0	0.0	36.2	29.0
TOTAL	232.1	96.5	51.5	22.9	11.0	9.0	0.0	25.2	2441.0
ZONE 13									
EATON	1.8	0.8	0.4	0.1	0.1	0.2	0.0	40.0	32.0
HILLSDALE	227.0	108.0	62.0	15.6	10.8	19.2	0.0	32.1	3469.0
INGHAM	31.0	15.0	8.2	1.5	1.5	3.7	0.0	38.2	574.0
JACKSON	175.5	77.3	43.0	7.7	7.7	19.7	0.0	38.9	3013.0
LENAWEE	7.0	3.5	2.1	0.7	0.3	0.3	0.0	31.1	109.0
TOTAL	442.3	204.6	115.7	25.6	20.4	43.1	0.0	35.1	7197.0
ZONE 14									
HILLSDALE	43.2	34.4	20.7	6.9	0.0	6.9	0.0	9.6	332.0
LENAWEE	135.0	79.2	48.2	15.1	0.6	14.8	0.0	10.2	810.0
OAKLAND	6.0	3.0	1.8	0.6	0.3	0.3	0.0	25.6	76.8
WASHTENAW	181.2	73.0	46.8	12.7	6.5	8.8	0.0	27.5	2007.5
WAYNE	0.8	0.4	0.2	0.2	0.0	0.0	0.0	24.2	9.7
TOTAL	366.2	190.0	117.7	35.5	7.4	30.8	0.0	17.0	3236.0
ZONE 15									
LENAWEE	17.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	[illegible]
OAKLAND	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WASHTENAW	14.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WAYNE	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	40.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ZONE 16									
LENAWEE	181.5	137.3	73.7	35.9	1.4	25.2	0.0	16.1	2217.0
MONROE	156.0	133.0	54.9	49.6	19.4	7.0	0.0	24.9	3323.0
WASHTENAW	49.0	39.5	20.9	11.6	5.5	1.9	0.0	27.9	1103.5
WAYNE	24.7	20.6	9.2	7.4	2.9	1.0	0.0	28.9	596.0
TOTAL	411.2	330.4	158.7	104.5	29.2	35.1	0.0	21.9	7239.5
ZONE 17									
BAY	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HURON	8.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	23.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SECTION III

CONCEPTUAL DESIGN OF WASTEWATER TREATMENT ZONES

Usable agricultural land is distributed throughout the wastewater treatment zones. In Section IV, unit costs (e.g., cost/acre of usable agricultural land) will be developed and multiplied by the usable acreage to obtain total costs for each component of the land treatment system. Thus, the precise location of the usable agricultural land is not determined in this study.

Design assumptions for each component of the land treatment system were made to develop subsequent unit costs. Hence, this section describes the design assumption for farm management, distribution of wastewater within the irrigation zones, irrigation of the wastewater, collection and discharge of the renovated wastewater, and finally monitoring, administration, and operations of the land treatment system.

FARM MANAGEMENT

Cooperating landowners receive (i) wastewater containing plant nutrients, (ii) irrigation equipment, and (iii) tile drainage. Landowners could form cooperatives and contract as a group to receive the wastewater. Such cooperatives have been formed in various parts of the world. One example is Braunschweig, Germany. Conceivably, farm cooperatives would

work in Southeastern Michigan. However, such cooperatives may tend to negate some of the individual management rights commonly expected by Michigan farmers. Hence, the individual farmer rather than a cooperative contracts for the wastewater.

Each individual farmer selects the agricultural crops and their rotation for his farm. Perhaps, this cropping system would be the same as the one already used for many years; or, the farmer may choose a different cropping system based upon the knowledge that water, irrigation, and drainage will be available.

The selected cropping system for a particular soil determines the amount of wastewater an individual farmer may apply during the year. The wastewater must be applied according to an established irrigation schedule. Representative irrigation schedules for various crops and soils were presented in the Phase III Report (5). At a later date, an individual farmer might desire a different cropping system. Within a large irrigation zone, cropping system changes could be allowed. These changes should not significantly alter the demand for wastewater. For example, when one farmer elects to discontinue growing corn, another farmer within the same irrigation zone may decide to start growing corn or another crop which requires about the same amount of wastewater.

Each individual farm possesses an independent irrigation system, i.e., one complete irrigation system per farm. This practice allows the farmer

greater flexibility in his management program. He or his representative can turn the irrigation system on or off, depending upon his needs. As previously mentioned, the water must be applied according to an irrigation schedule. Thus, the individual farmer would not have complete freedom in deciding when to irrigate. However, he could decide whether to irrigate during the first week or the second week of a month, and when within the selected week to irrigate. This procedure allows the farmer to schedule his planting, harvesting, vacation and holidays, etc.

Also, an independent irrigation system for each farm allows the farmer greater freedom in selecting cropping rotations. Different crops must be irrigated at different times with varying quantities of water. Hence, neighboring farmers can plan their rotations without being dependent upon each other to grow the same crop on adjacent property land.

As in the case without wastewater application, each individual farmer would be responsible for the management of his farm. He could continue to plant the crop, apply supplemental fertilizers, herbicides and pesticides, harvest the crop, and market the resulting product. One additional farm management responsibility is the application of the wastewater as stipulated in a contract. Once the contract is executed, the farmer would be expected to receive wastewater for a reasonable number of years.

Within a given irrigation area, nearly all farmers with usable cropland are eventually expected to be recipients of wastewater. Initially, some farmers probably will not want to participate. This would be acceptable until the wastewater flow matches the design flow of 2.7 billion gallons per day projected for the year 1990. At this point, nearly all farmers are assumed to receive their allocated wastewater.

Management arrangements between the cooperating farmers and the agency providing wastewater will be discussed in another section of the CORPS' Survey Report.

WASTEWATER DISTRIBUTION WITHIN THE ZONE

Sewage from the Southeastern Michigan area will be collected, treated and stored in lagoon systems. The resultant wastewater will be disinfected and transmitted to selected delivery points within the wastewater treatment zones. Other sections of the CORPS' Survey Report will present designs and costs for this portion of the study.

Within the zone or selected subdivision of the zone, wastewater must be distributed from the delivery point to the individual farms considered for wastewater application. This distribution system consists of open canals and/or buried pressure pipes. On relatively flat terrain with an average slope of <0.2%, the distribution system consists of canals and pressure pipes.

Canals will serve as the mains; pressure pipes will be the laterals. Land for the canals will be acquired, fenced, and maintained by the agency controlling the wastewater treatment program. Suitable pump stations will be employed to deliver the wastewater under pressure from the canals to the individual farms.

On more hilly terrain with an average slope of >0.2%, the distribution system consists of only pressure pipes. Again, pump stations are employed to deliver the wastewater under pressure to the farms.

The distribution system is sized to accommodate the maximum amount of wastewater needed for a week. The amount of water needed per week is taken from the projected irrigation schedules for specific crops given in Table 18a of the Phase III Report (5). The maximum amount needed usually occurs during July or August and ranges from 5-8 inches per month or about 1.25-2.0 inches per week. For Soil Management Group 1 abc, the maximum amount is assumed to be 1.0 inch per week.

The distribution system is further sized to accommodate the weekly maximum quantity in 80 hours during the week. The 80 hours time span corresponds to the irrigation period assumed to be the shortest period in which farmers within an irrigation zone or subzone will want irrigation water. Rainy periods will likely prevent continuous irrigation. Farmers may not particularly want to irrigate on holidays and perhaps on Sundays. Hence, 80 hours per week was arrived at by assuming five working days at 16 hours each.

IRRIGATION

The wastewater is delivered in pressure pipes to the individual farms. As previously mentioned, each farm has appropriate valves and a complete irrigation system independent of neighboring systems.

Several irrigation methods are suitable for applying the wastewater. These methods include fixed-set sprinkler system, center pivot sprinkler system, and surface irrigation systems such as graded border or ridge and furrow. Each method has advantages and disadvantages that determine its acceptability for wastewater applications in Southeastern Michigan.

The major advantages of the fixed-set system include (i) adaptability to any crop, soil type, terrain, and shape and size of field, (ii) low operational labor requirement, and (iii) low application rate (12). The major disadvantage is the relatively high capital cost compared with other systems. The fixed-set system may be 5-7 times the capital cost for the center pivot irrigation system (3, 12). The application rate can be easily varied from 0.1-0.4 inches per hour. Lateral and spray nozzle spacings are determined by the selected application rate. Generally, high application rates result in wide lateral and nozzle spacings. A representative design for a fixed-set system is shown in Figure III-6 of the Phase I-Phase II Report (3).

The center pivot sprinkler system generally has a lower capital cost, but higher labor and maintenance cost than fixed-set systems. One chief disadvantage

is the high application rate at the far end of the pivot system (Table IV). Because each succeeding sprinkler head on the system must move farther and faster than the one before it, more water must be applied per foot of system length toward the far end (12). The outer one-quarter of the sprinkler system covers one-half of the area. Consequently, the sprinklers on the outer end have a high capacity and apply water at a faster rate to obtain a uniform depth of application throughout the field (12). Another disadvantage is the design difficulty in fitting center pivot systems onto irregularly-shaped and relatively small irrigation fields. For example, small center-pivot systems with a radius of about 600 feet are more easily fitted than are longer systems of say 1300-2000 feet. Representative designs for center-pivot systems are shown in Figures III-4, III-5, and III-6 in the Phase I-Phase II Report (3).

Surface irrigation such as graded border or ridge and furrow possesses capital and operating-maintenance costs similar to the center pivot system. Surface irrigation methods require gently sloping fields, either naturally or through land grading. This type of irrigation is not commonly practiced in Michigan. A representative design for graded border and irrigation is shown in Figures III-7, Phase I-Phase II Report (3).

Other methods of irrigation may be acceptable for wastewater applications under certain conditions. These include traveling gun sprinkler, side-roll lateral sprinkler, contour levee surface irrigation, etc.

Table IV

Application Rates Using Center Pivot Sprinkler System for Various Water Quantities Applied in 80 Hours Spray Time Assuming 100 Foot Wide Spray Pattern

Application Rate (In/Week)	Distance From Pivot (Feet)	Revolutions Per 80 Hrs.	Duration (Hours)	Instantaneous Application Rate (In/Hour)	Inches per Revolution
0.5	600	1	2.12	0.24	0.5
	1300	1	0.98	0.51	0.5
	600	5	0.42	0.24	0.1
	1300	5	0.20	0.51	0.1
1.0	600	1	2.12	0.47	1.0
	1300	1	0.98	1.02	1.0
	600	5	0.42	0.47	0.2
	1300	5	0.20	1.02	0.2
2.0	600	1	2.12	0.94	2.0
	1300	1	0.98	2.04	2.0
	600	5	0.42	0.94	0.4
	1300	5	0.20	2.04	0.4

From the several possible irrigation methods, fixed-set and center pivot irrigation are selected as the most suitable for wastewater application in Southeastern Michigan. The fixed-set is selected primarily because of its low application rates and adaptability to small irrigation areas such as would be encountered on individual farms especially with less than about 250 acres. The center pivot is selected primarily because of its low capital costs. Surface irrigation could be practiced, but is believed unacceptable to some farmers because of the extensive land grading which may be required.

The application rate of the selected irrigation method must be less than the water infiltration rate of the soils to avoid water runoff and soil erosion problems. Suggested application rates for soil management groups are listed on page 57 of the Phase III Report (5). For soil management groups 1, 1.5, 2.5, 3, and 3.5, only fixed-set sprinkler irrigation is acceptable because of the lower application rate requirement. However, center pivot irrigation and the resulting higher application rate is assumed acceptable in some cases for soil management groups 4 and 5. In this latter case, acceptability of the center pivot is likely dependent upon farm size. Farms with 250 or more acres can accommodate center pivots and likely have sufficient crop rotation flexibility. However, center pivots are more difficult to adapt to smaller farms; i.e., less than 250 acres in size, and still maintain crop rotation flexibility. Accordingly, 25% of the land in Soil Management Groups 4 and 5 is assumed irrigible with the center-pivot sprinkler system.

As suggested in Table IV, the application rate at the far end of the center pivot system might exceed the suggested application rate given in the Phase III Report (5). This is especially true for the 1300 foot system as compared to the 600 foot system. Hence, the 600 foot system will be more frequently used to maintain acceptable wastewater application rates. Several management manipulations can be made to insure that the application rate for 600 foot center pivot system will be less than the soil infiltration rate. Irrigation periods of short duration should favor higher water infiltration rates for a particular soil. Generally, soils have higher infiltration rates during the first part of the wetting period. Also, a cover crop improves the infiltration rate.

Table V shows the selected irrigation method and application rate for the various soil management groups. The 0.2 inch per hour application rate was selected to minimize capital cost for the fixed-set system. Generally, capital costs increase with higher application rates (12).

COLLECTION AND DISCHARGE

Many of the Southeastern Michigan soils are poorly drained and/or have a naturally occurring high water table. In these soils, a tile drainage system is necessary to maintain aerobic conditions. Aerobic conditions in the soils are required for wastewater renovation and maximum crop production. The tile drainage system also collects the renovated wastewater for possible reuse and/or discharge into adjacent streams.

Table V

Selected Irrigation Method and Application Rate for Soil Management Groups

Soil Management Group	Suggested Application Rate (In/Hour)+	Selected Irrigation Method	Farm Size (Acres)	Selected Application Rate (In/Hour)
1	0.05-0.1	None	--	None
1.5	0.1	Fixed-Set	--	0.1
2.5	0.25	Fixed-Set	--	0.2
3	0.35	Fixed-Set	--	0.2
3/5	0.35	Fixed-Set	--	0.2
4	0.5	Fixed-Set Center Pivot	<250 >250	0.2 Variable++
5	1.0	Fixed-Set Center Pivot	<250 >250	0.2 Variable++

+From page 57, Phase III Report

++Application rate increases from pivot point to system end. See Table IV.

The tile drains are placed about six feet beneath the soil surface. This depth allows the wastewater to be exposed to the maximum practical soil volume before entering the drainage system. The Donnan Equation, as discussed in the Phase I-Phase II Report (3), was used to design the tile drainage system. Soil permeability, which is considered in the Donnan Equation, was assigned to soil management groups. The assigned permeabilities and resulting tile spacings are shown in Table VI.

From the tile drainage system, the renovated wastewater flows by gravity through submains and mains to low head pumps. At this point, the collected percolate is lifted into a canal or pressure pipe for transmission to the reuse pond. The choice of gravity canals or pressure pipe depends on the terrain. Gravity canals are used in relatively flat terrain with an average slope of <0.2%; pressure pipes in more hilly terrain with an average slope of >0.2%, and where the watershed drains west toward Lake Michigan or south toward Ohio.

Table VI

Selected Soil Permeability for Estimating Tile Drain Spacings

Soil Management Group	Soil Permeability (In./Hour)	Calculated Tile Spacings (Feet)
1.5	0.2	40-45
2	0.2	40-45
3	0.5	60-70
4	1.0	---
5	2.0	125-135

Reuse storage ponds are located at low drainage points near streams. The reuse ponds are sized to retain about a 10-day flow of collected percolate. Under normal conditions, the water will flow through the pond to the receiving body of water. The need for reuse storage facilities is discussed further in the Phase I-Phase II Report (3).

The collected percolate will be routed to discharge points on adjacent streams through open canals. An outfall structure is required to blend the discharge flow with existing stream flow to minimize the hydraulic disturbance of the existing stream.

As an alternative to the reuse pond and subsequent discharge into adjacent stream, the collected percolate could be discharged in a rapid infiltration basin. This water could then recharge groundwater aquifer. Geological studies are required to locate suitable sites and to establish the need for rapid infiltration basins.

MONITORING, ADMINISTRATION, AND OPERATION

Considerable sampling and testing must be conducted to determine the effectiveness of land treatment for wastewater renovation and also to develop irrigation, drainage, and farm management practices.

This sampling and testing will be conducted by a central laboratory responsible for all wastewater treatment zones. Monitoring includes groundwater via observation wells, reuse pond influent and effluent, above and below stream discharge points, plant, and soil samples. Further discussion on the sampling and testing program is given in the Phase I-Phase II Report (3).

Numerous administrative, technical, and operating personnel are required to man the land treatment facilities for Southeastern Michigan. Personnel are required at the project, site or zone, and local or work unit levels. Examples of the required personnel are contained in the Phase I-Phase II Report (3).

ILLUSTRATIONS

Thus far, this section has verbally described the land treatment concept. Figures 2 and 3 are illustrations or "artist concepts" of hypothetical area containing urban, forest, recreational, and farm lands. Figure 2 shows wastewater distributed to usable agricultural lands, where the water is irrigated via center pivot and fixed-set sprinkler systems. Each farm has an independent irrigation system with a valve so that the water can be turned on or off at the individual farm level.

Figure 3 shows the same area with tile drainage so that the renovated wastewater can be collected, transmitted to reuse ponds, and eventually discharged into an adjacent stream.

These figures show only the main features of the system. Buffer strips, pressure reducers, check dams, etc., are considered part of a final design.

SUMMARY OF DESIGN DATA

In the next section, costs will be based on the capacity of the distribution system; the irrigation method, application rate, and farm size; soil permeability values; etc. In this section, many of these variables were related to soil management groups; but, crop projection, land use, and wastewater application data are related to soil associations. Further, the soil map in Figure 1 gives locations of soil associations rather than soil management groups. Table II of the Phase III Report (5) lists the dominant soil management groups for each soil association. This information is retabulated in Table VII of this section. Also, Table VII summarizes the values used for the distribution system size, irrigation methods, and soil permeability according to soil associations. This table is based on data presented earlier in this section and in Tables V and VI.

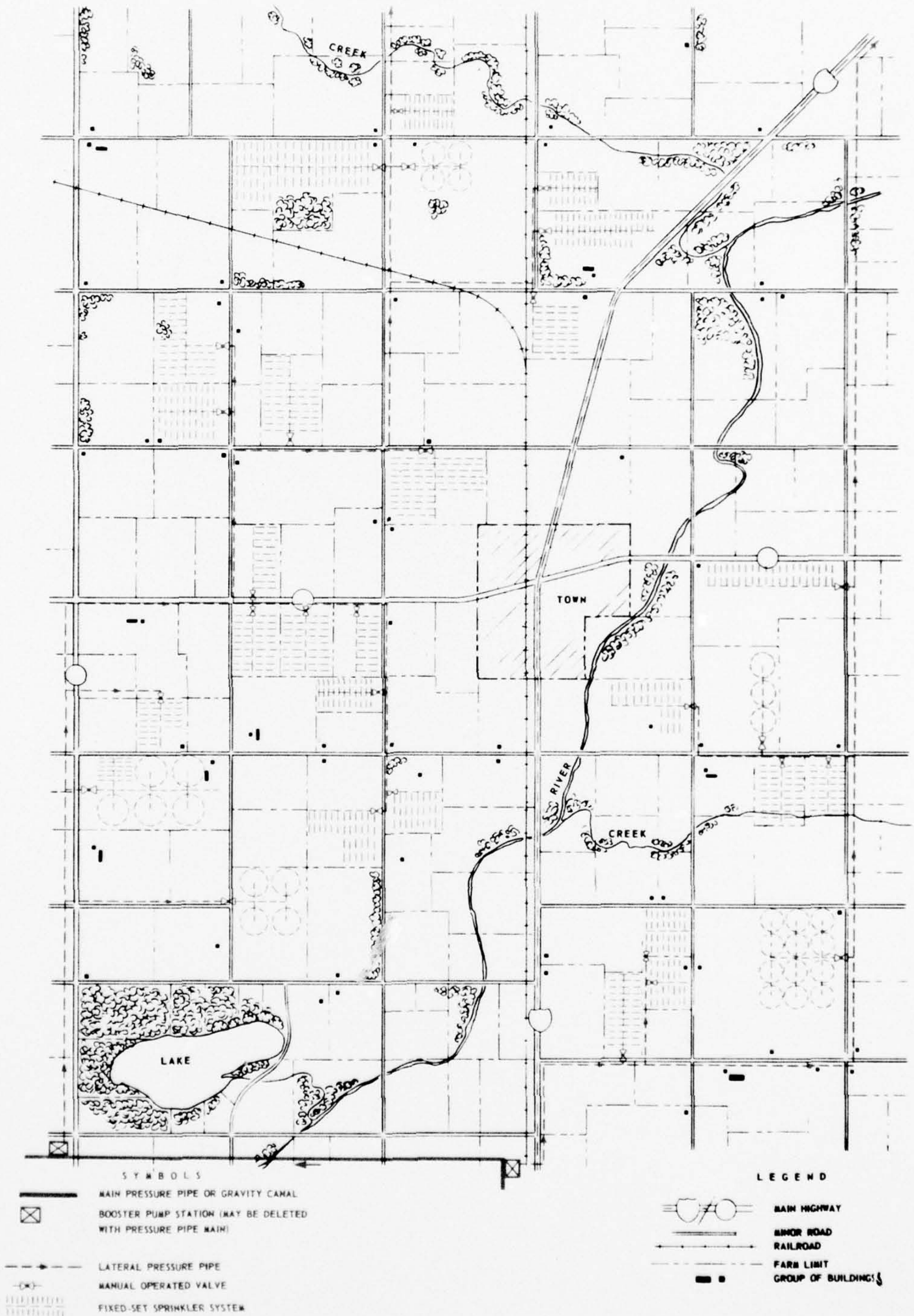


Figure 2

Distribution and Irrigation System on
Hypothetical Area in Southeastern Michigan

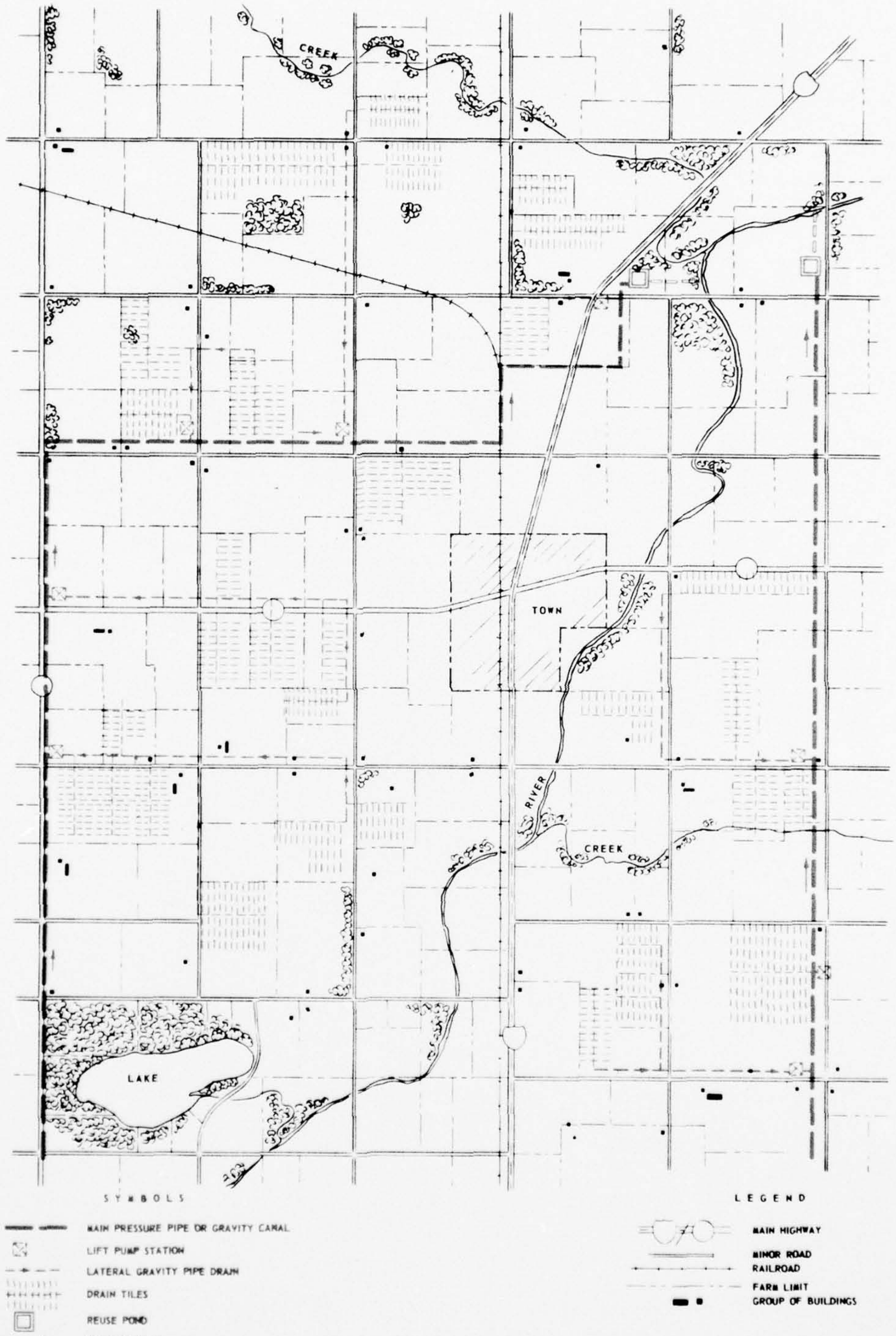


Figure 3

Drainage and Collection Systems on Hypothetical Area in Southeastern Michigan

In Section IV, costs are tabulated by county for each wastewater treatment zone. Several soil associations usually occur in each county subzone (Figure 1). Hence, the data in Table VII were averaged according to the usable agricultural land in each soil association. These averaged values will appear in the cost tables of Section IV and were used to select appropriate unit costs.

Table VII

Summary of Design Data Related to Soil Association

Soil Association	Soil Management Groups	Maximum Irrigation of Crops+ (Inches/Week)	Selected Irrigation Method and Application Rate (Inches/Hour)	Soil Permeability (Inches/Hour)
D	0, 1	--	--	--
E	1	--	--	--
F	1, 1.5	1.0	FS-0.1 - 100%++	0.2
G	1, 1.5	1.0	FS-0.1 - 100%	0.2
H	1.5, 2.5, 4/2, 3/2	1.25	FS-0.1 - 50% FS-0.2 - 50%	0.2
I	1.5, 2.5, 4/2, 3/2	1.25	FS-0.1 - 50% FS-0.2 - 50%	0.2
J	1.5, 3/2, 4/2	1.25	FS-0.1 - 50% FS-0.2 - 50%	0.2
K	1.5, 2.5	1.25	FS-0.1 - 50% FS-0.2 - 50%	0.2
L	1.5, 2.5, 4/2	1.25	FS-0.1 - 50% FS-0.2 - 50%	0.2
Mn	1.5, 2.5, 3/2, 4/2	1.25	FS-0.1 - 50% FS-0.1 - 50%	0.2
Ms	1.5, 2.5, 3/2, 4/2	1.25	FS-0.1 - 50% FS-0.1 - 50%	0.2

Table VII (Cont.)

Soil Association	Soil Management Groups	Maximum Irrigation of Crops[+] (Inches/Week)	Selected Irrigation Method and Application Rate (Inches/Hour)[++]	Soil Permeability (Inches/Hour)
N	3, 4	2.0	FS-0.2 - 85% CP - 15%	0.75
O	2.5, 3, 4	1.75	FS-0.2 - 90% CP - 10%	0.50
P	3/5, 4	2.0	FS-0.2 - 85% CP - 15%	0.75
Q	3/5, 4	2.0	FS-0.2 - 85% CP - 15%	0.75
R	4, 3/5, 4/2	1.75	FS-0.2 - 90% CP - 10%	0.50
S	4	2.0	FS-0.2 - 75% CP - 25%	1.5
T	4, 5	2.0	FS-0.2 - 75% CP - 25%	1.5
U	4, 5	2.0	FS-0.2 - 75% CP - 25%	1.5
V	5	2.0	FS-0.2 - 75% CP - 25%	2.0
W	5	2.0	FS-0.2 - 75% CP - 25%	2.0
X	Mc	--	--	--

[+] These values are subsequently used to size the distribution system.

[++] FS = Fixed-set sprinkler system, CP = center-pivot sprinkler system; 0.1 or 0.2 = application rate; percentage of usable cropland irrigated by this method.

AD-A041 125 MICHIGAN STATE UNIV EAST LANSING DEPT OF CROP AND SO--ETC F/G 13/2
LAND TREATMENT OF WASTEWATER IN SOUTHEASTERN MICHIGAN.(U)
JUL 73 DACW35-73-C-0163
UNCLASSIFIED NL

3 OF 3
AD A041125

END
DATE FILMED
7-77

SECTION IV

UNIT COSTS AND COST SUMMATIONS

This section describes the design approach used to develop unit costs and energy requirements for the irrigation method, distribution system, collection system, and project administration. Unit costs are subsequently used to obtain total costs which are tabulated by counties within each wastewater treatment zone. Eventually, others will select entire zones and possibly county portions of some other zones to treat the wastewater produced in Southeastern Michigan. Thus, total cost for the land treatment of this wastewater can be obtained by summing the costs for the selected zones and county portions of zones.

Costs are estimated in January 1972 dollars with no adjustment for future inflation. No allowance is made for taxes, insurance, nor engineering. Maximum use is made of pertinent data from the PhaseI-Phase II Report (3) to develop costs for this study.

IRRIGATION METHOD

Center-pivot and fixed-set sprinkler systems were the selected irrigation methods as discussed previously in Section III of this report. Further descriptions of these irrigation methods are given in the Phase I-Phase II Report (3).

Center-Pivot Sprinkler System

The center-pivot system consists of self-propelled truss sections rotating about the pivot point. Each section has a lateral line with spray nozzles and an electric motor.

Three different farm sizes, 124, 475, and 2436 acres, are used to develop Figure 4 which shows the cost per acre as a function of the area. Figure 4 includes costs for irrigation rigs, pipes, valves, and miscellaneous. Table VIII shows the capital cost distribution.

Table VIII

Distribution of Capital Costs for Center-Pivot Sprinkler Systems

	Average Capital Cost Distribution Percent (%)		
Area (Acres)	Rigs	Valves & Misc.	Pipes
124	39.1	4.4	56.5
475	38.3	3.7	58.0
2436	26.2	2.0	71.8

The maintenance, supplies and replacement cost shown in Figure 5 is derived from the Phase I-Phase II Report (3) and the capital cost distribution shown in Table VIII. The annual labor cost is taken at $16.20 per acre. This represents 60% of the total labor cost for operating the irrigation, drainage, and collection system as given in the Phase I-Phase II Report (3). This percentage of the total labor requirement is judged to be a reasonable estimate for irrigation portion of the total labor.

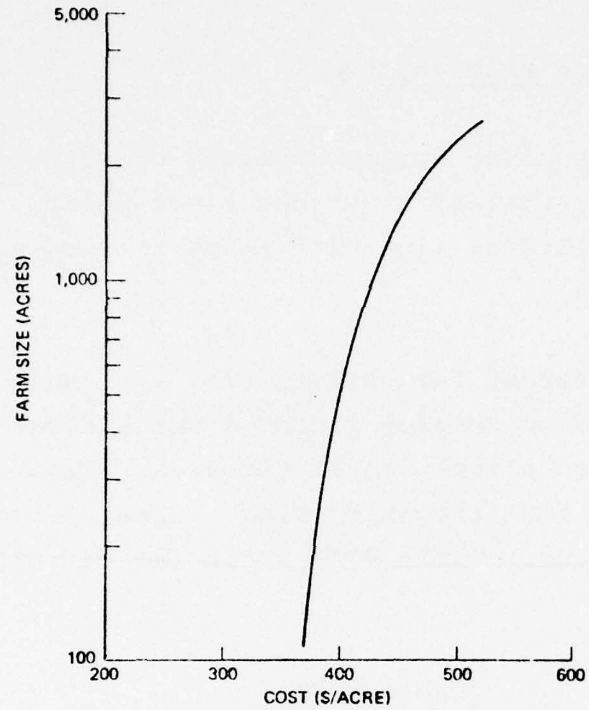


Figure 4

Capital Cost for Center-Pivot Sprinkler System

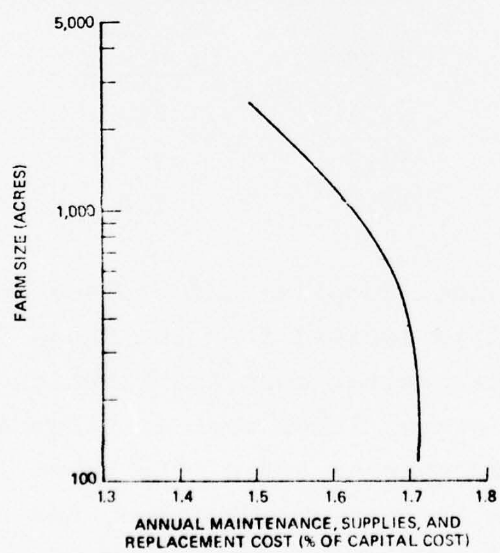


Figure 5

Annual Maintenance, Supplies, and Replacement Cost for Center-Pivot Irrigation

The annual electric power required to operate the electric motors is 106.4 Kw-Hr per acre. This value is based on 2800 hours of operation per year. The annual cost of energy is $1.33 per acre, based on the Phase I-Phase II Report (3) cost of $0.0125 per Kw-Hr.

Fixed-Set Sprinkler System

The fixed-set system consists of a permanent underground network of mains, sub-mains, laterals and spray nozzles. The spacing of the nozzles depends on the application rate. For this study, an operating pressure of 50 psi at the spray nozzle is used for application rates of 0.1, 0.2, 0.3, and 0.4 inches per hour.

Three different farm sizes, 160, 640, and 2560 acres, are used to develop Figure 6 which shows the cost per acre as a function of the area for the different application rates. Figure 6 includes costs for spray nozzles, saddles, risers, mains, sub-mains, and laterals. An additional 2.0% is included for valves and miscellaneous items. Table IX shows the capital cost distribution.

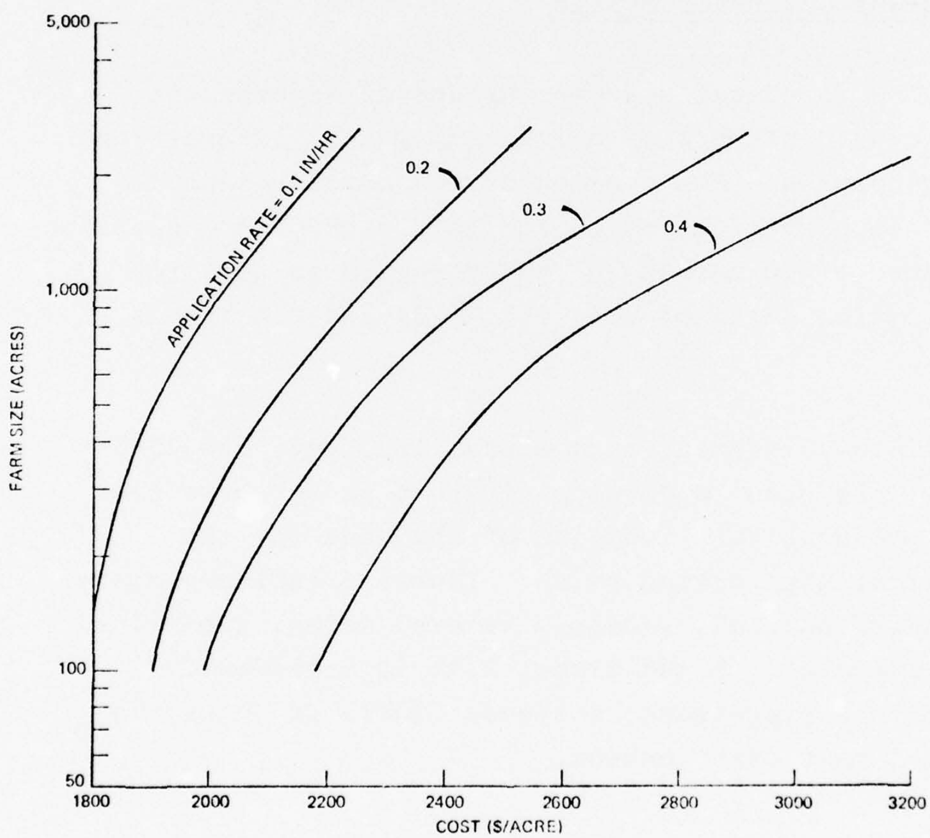


Figure 6

Capital Cost for Fixed-Set Sprinkler System

Table IX

Distribution of Capital Costs and Annual Maintenance, Supplies and Replacement Costs for Fixed-Set Sprinkler Systems

Application Rate (In/Hr)	Average Capital Cost Distribution-Percent (%): Sprinkler Heads	Saddles, Risers, Valves & Misc.	Pipes	Annual Maintenance Supplies & Replacement Cost (Percent of Capital Cost)
0.1	12.4	21.0	66.6	4.1
0.2	6.4	14.6	79.0	2.8
0.3	4.8	11.2	84.0	2.2
0.4	2.9	7.9	89.2	1.9

The maintenance, supplies and replacement costs are derived from Phase I-Phase II Report (3) and the capital cost distribution in Table IX. The annual labor cost is taken at $16.20 per acre as mentioned earlier for the center-pivot system. Power is not required for the fixed-set system since the water is delivered under pressure to the individual farm.

DISTRIBUTION SYSTEM

The distribution system consists of a main distribution clay-lined canal or pressure pipe. Pressure pipe laterals convey the water to the individual farms. For this study, laterals are assumed spaced at 2.0 mile intervals. The capacity of the system is based on a minimum irrigation time of 80 hours per week.

Three system sizes, 10,000, 52,000, and 180,000 acres, are used to develop Figure 7 which shows the capital cost per acre as a function of the system area for system capacities of 0.5, 1.0, and 2.0 inches per week. There are two families of curves, one using pressure pipe as the distribution main, and the other using a gravity canal. They are identified respectively as PIPE and CANAL.

Figure 7 includes costs for lateral and main pipes, main canals, booster pump stations at laterals, and a main pump station at pressure main. An additional 5% is included for valves, gates and miscellaneous structures. Table X shows the capital cost distribution.

Table X

Capital Cost Distribution for the Wastewater Distribution System

		Avg. Capital Cost Distribution Percent (%)			
System	Area (Acres)	Pump Stations	Pressure Laterals	Main Pipe or Canal	Misc.
	10,000	15.0	34.6	43.6	6.8
PIPE	52,000	5.6	50.9	38.5	5.0
	180,000	3.2	60.2	31.9	4.7
	10,000	28.1	40.0	27.0	4.9
CANAL	52,000	14.1	73.3	8.2	4.4
	180,000	6.7	84.9	3.8	4.6

The maintenance, supplies and replacement cost shown in Figure 8 is derived from the Phase I-Phase II Report (3) and the capital cost distribution shown in

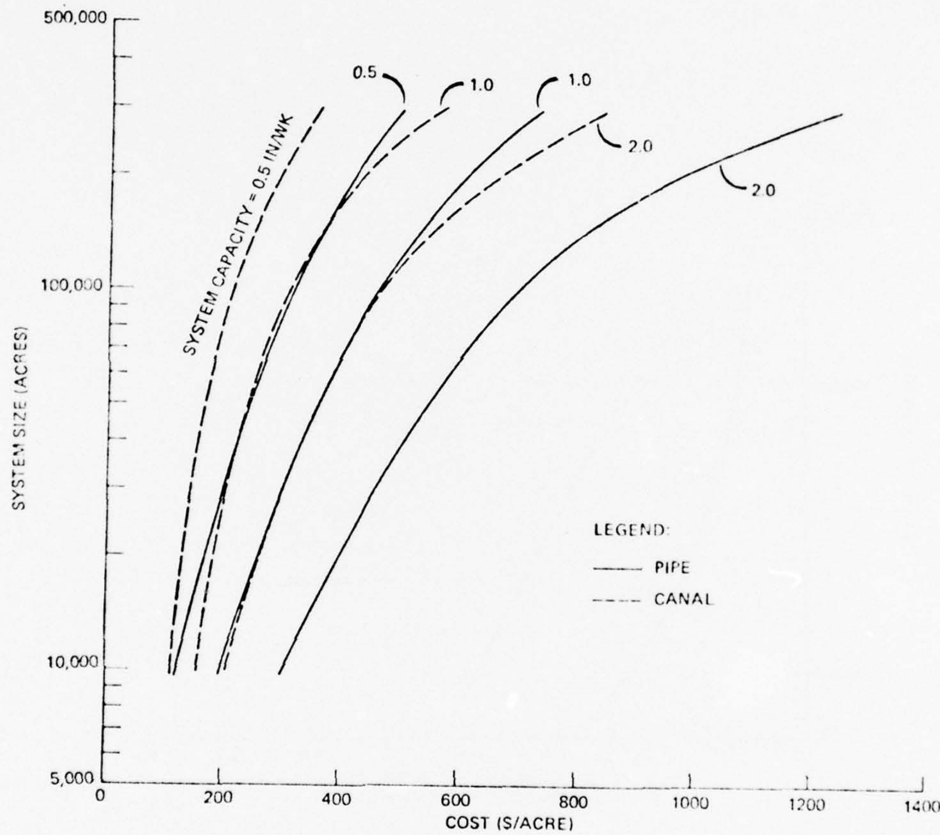


Figure 7

Capital Cost for the Distribution System

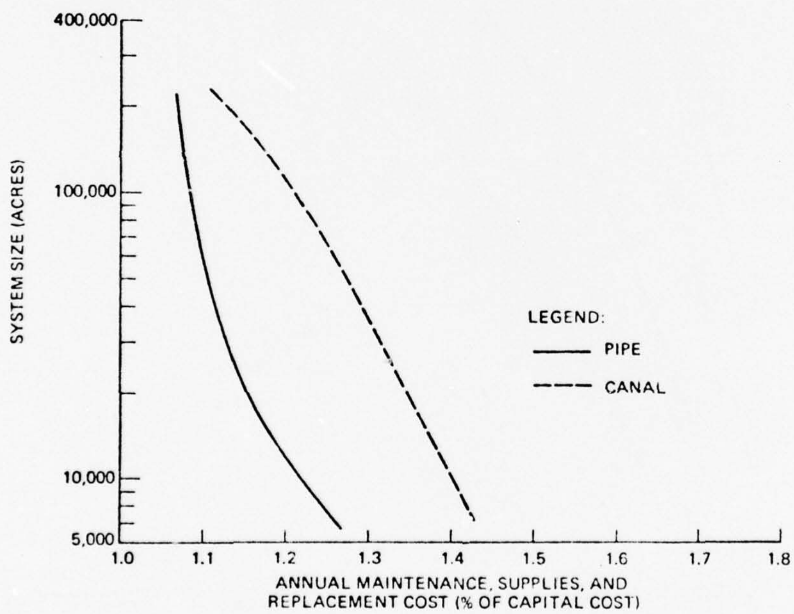


Figure 8

Annual Maintenance, Supplies, and Replacement Cost for the Wastewater Distribution System

Table X. The annual labor cost is taken at $6.80 per acre. This represents 25% of the total labor cost for operating the irrigation, distribution, and collection systems, as given in the Phase I-Phase II Report (3). The annual electric power required is 22.3 Kw-Hr per acre-inch for the gravity (CANAL) system, and 26.3 Kw-Hr per acre-inch for the pressure (PIPE) system. These values are based on an average design pumping head of 170 feet for the gravity system, and 200 feet for the pressure system. The annual cost of energy is $0.279 and $0.328 per acre-inch for the gravity and pressure systems respectively. These costs are based on the Phase I-Phase II Report (3) cost of $0.0125 per Kw-Hr.

COLLECTION SYSTEM

The collection system consists of tile drains, lateral pipes, lift stations, main collection unlined canals or pressure pipes, and reuse ponds sized to retain 10 days of flow.

For this study, the drainage rate is assumed at 0.02 inches per hour; and the minimum tile depth is six feet. Tile spacings are determined from the soil permeability values. Soil permeability values of 0.2, 0.5, and 2.0 inches per hour are used to develop Figure 9. System sizes of 1380, 5510, 22,000, and 88,000 acres were also used for Figure 9 which shows the cost per acre as a function of the system size for the different soil permeabilities. Figure 9 contains two families of curves, one for the system using a pressure pipe as the collecting main and another

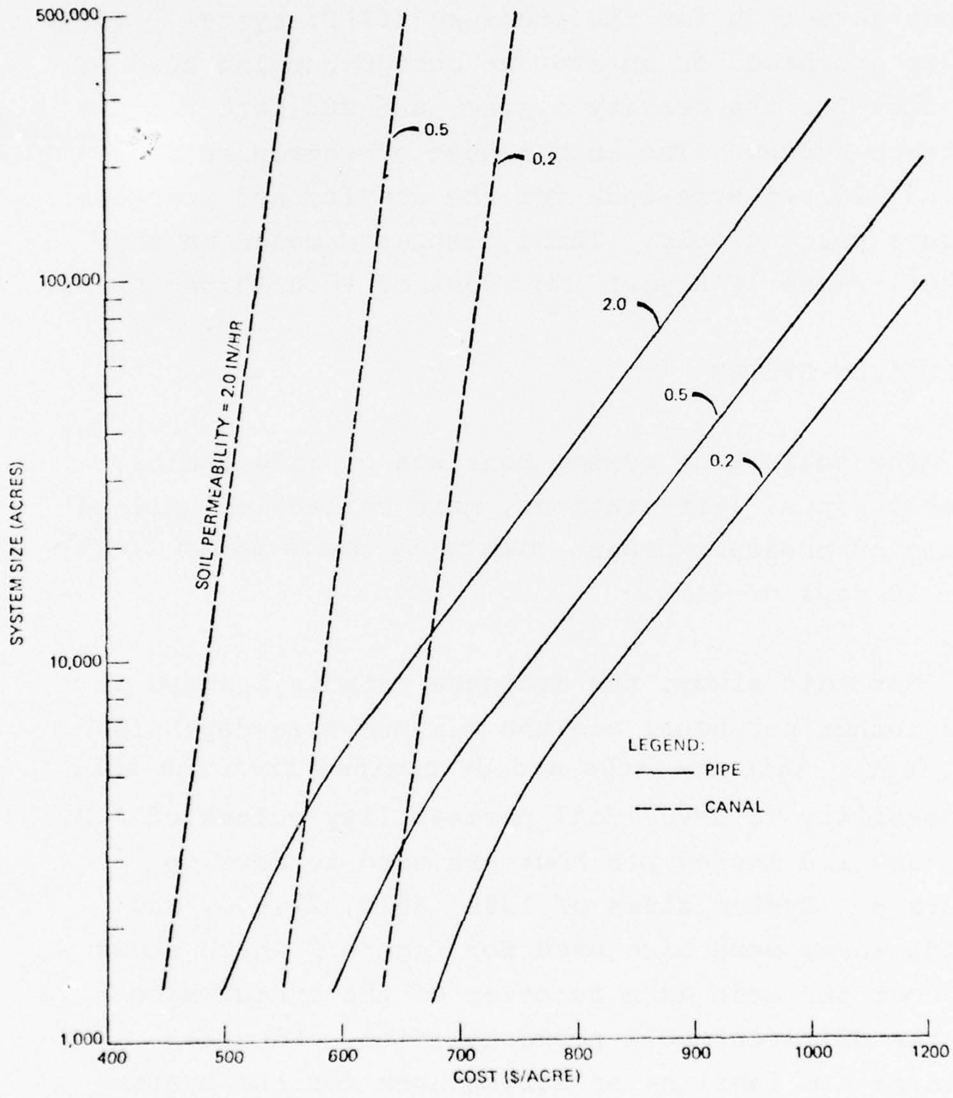


Figure 9

Capital Costs for the Collection System

for the system using a gravity canal. They are identified respectively as PIPE and CANAL.

Figure 9 includes costs for the tile system, lift stations, pipe, canal, and reuse pond. An additional 5% is included for miscellaneous. Table XI shows the cost distribution.

Table XI

Distribution of Capital Costs and Annual Maintenance, Supplies and Replacement Costs for the Collection System

	Avg. Capital Cost Distribution - Percent (%)					Annual Maintenance, Supplies & Replacement Cost (Percent of Capital Cost)
System	Pump Stations	Pipes	Canals	Storage	Misc.	
PIPE	12.5	72.2	----	10.6	4.7	1.86
CANAL	8.7	60.0	12.7	13.6	5.0	1.69

The maintenance, supplies and replacement cost is derived from Phase I-Phase II Report (3) and the capital cost distribution is shown in Table XI. The annual labor cost is taken at $4.00 per acre. This represents 15% of the total labor cost as given in the Phase I-Phase II Report (3) for the irrigation, distribution, and collection system.

The annual electric power required is 2.64 Kw-Hr per acre-inch for the gravity (CANAL) system, and 13.12 Kw-Hr per acre-inch for the pressure (PIPE) system. These values are based on an average design pumping

head of 20 feet for the gravity system, and 100 feet for the pressure system. The annual cost of energy is $0.033 and $0.164 per acre-inch for the gravity and pressure systems, respectively. These costs are based on the Phase I-Phase II Report (3) cost of $0.0125 per Kw-Hr.

PROJECT ADMINISTRATION

The project administration in this report comprises the equivalent costs of the Project Administrative and Central Lab from Table IV-30 of the Phase I-Phase II Report (3). Also, project administration includes the equivalent costs for outfalls, observation wells and general site items such as electrical, field service buildings, and site administration from Tables VI-2, VI-3, VI-4 and VI-5 of the Phase I-Phase II Report (3).

Capital cost is taken as $0.0135 per acre-inch, plus 3.5% of the capital cost of the irrigation method, distribution, and collection systems. Operation and maintenance cost is taken as $0.0135 per acre-inch, plus 10% of the capital cost.

COST SUMMATIONS

Tables XII-XVII present the cost data by counties within each wastewater treatment zone. Zones V, VIII, XV, and XVII are excluded from these tables because they do not have any usable land for irrigation.

Table XII shows the capital cost for the irrigation method. The first two columns are taken from Table III (Section II). The selection of center-pivot or fixed-set, as well as the application rate and the percent of the area is based on Table VII (Section III) and the map in Figure 1 (Section II). The cost per acre comes from Figures 4 and 5. The average farm size was obtained from 1969 census data. The average farm size for areas using center-pivot sprinkler systems was assumed to be 400 acres. The irrigation method total cost column is the summation of the products of the usable agricultural land, the percent of the area using a particular type, and the associated cost per acre.

Table XIII shows the capital cost for the distribution system, the collection system, and the project administration. Again, the first two columns were taken from Table III (Section II). The system size is determined from topographic maps considering river basins, urban and recreational areas, forests, and any other pertinent factor limiting the size of the system, and the county areas within a particular wastewater treatment zone. Because of these considerations, Saginaw County in Zone IV, and Lapeer County in Zone VI are sub-divided into different systems. The choice of the gravity (CANAL) or pressure (PIPE) system depends on the topography of the area. An average slope of 0.2% is used as the limiting value between gravity (CANAL) and pressure (PIPE) systems. For slopes smaller than 0.2% the gravity (CANAL) system is used. The pressure (PIPE) system is used for slopes larger than 0.2%.

Additionally, the pressure (PIPE) system was selected, regardless of slope, for those zones draining into Lake Michigan or Ohio. The gravity (CANAL) system is more economical than the pressure (PIPE) system, but with steep slopes the construction costs and problems will increase.

The system capacity and the soil permeability are selected from Table VII (Section III) and the map in Figure 1 (Section II). The cost per acre was taken from Figures 7 and 9. The total cost for the distribution and collection systems is the product of the usable agricultural land times the cost per acre. The administration costs were estimated as described earlier in this section.

Table XIV shows the annual operation and maintenance costs for the center-pivot, fixed-set, distribution system, collection system, and administration. Costs were taken from Figures 5 and 8 and from Tables IX and XI where appropriate. Other costs were used as discussed earlier in this section.

Table XV shows the total costs. The capital cost is the summation of the irrigation capital cost, the distribution system capital cost, the collection system capital cost, and the administration capital cost. The capital recovery in a 50 year period at an interest rate of 5.5% is computed as in the Phase I-Phase II Report (3) using a factor of 0.05906. The O&M column is the total from Table XIV. The total

annual cost is the sum of the capital recovery and O&M. The capital cost per million gallons is the capital divided by the water applied in millions of gallons (1 acre-inch = 27,154 gallons). The annual cost per million gallons is the total annual cost divided by the water applied in millions of gallons.

Table XVI shows the same information as Table XV but with interest rates of 7% and 10%. The applicable capital recovery factors are 0.07245 for 7%, and 0.10089 for 10%. The sinking fund factor for the replacement costs is taken as a proportion of the O&M costs from Table VI-8 of the Phase I-Phase II Report (3). For 7% the O&M cost is the product of the O&M for 5.5% times 0.9872. For 10% the O&M cost is the product of the O&M for 5.5% times 0.9673.

Energy requirements are displayed in Table XVII.

Table XII

IRRIGATION CAPITAL COST

COUNTY	USABLE AGRICULTURE LAND (1000 ACR)	TOTAL WATER APPLIED (ACR-IN/YR) (THOUSANDS)	CENTER PIVOT (AVERAGE FARM SIZE = 400 ACRES) AREA (%)	CENTER PIVOT COST PER ACRE ($1000)	AVERAGE FARM SIZE (ACRES)	FIXED SET RATE = 0.1 IN/HR AREA (%)	FIXED SET RATE = 0.1 IN/HR COST PER ACRE ($/ACRE)	FIXED SET RATE = 0.2 IN/HR AREA (%)	FIXED SET RATE = 0.2 IN/HR COST PER ACRE ($/ACRE)	IRRIGATION METHOD TOTAL COST ($1000)
ZONE 1										
ARENAC	62.8	1299.5	5	392	150	30	1805	65	1930	114020
BAY	23.3	447.2	5	392	125	45	1800	50	1920	41598
GLADWIN	38.6	846.0	0	0	175	50	1810	50	1950	72568
MIDLAND	34.6	889.7	10	392	150	20	1805	70	1930	60592
TOTAL	159.3	3482.4								288877
ZONE 2										
HURON	283.0	4972.0	1	392	175	45	1810.	54	1950	529412
LAPEER	1.0	22.0	0	0	150	50	1805	50	1930	1868
SANILAC	101.3	2386.0	1	392	175	45	1810	54	1950	189575
ST. CLAIR	11.2	217.0	0	0	125	50	1800	50	1920	20832
TUSCOLA	85.0	2105.0	5	392	150	10	1805	85	1930	156451
TOTAL	481.5	9702.0								898337
ZONE 3										
CLINTON	83.2	1544.7	0	0	150	50	1805	50	1930	155376
GRATIOT	136.0	2945.0	0	0	150	50	1805	50	1930	253980
MIDLAND	8.0	149.0	0	0	150	50	1805	50	1930	14940
TOTAL	227.2	4638.7								424296
ZONE 4										
ARENAC	12.4	169.5	0	0	175	50	1810	50	1950	23312
BAY	77.7	1445.0	0	0	125	50	1800	50	1920	144522
CLINTON	21.0	536.0	0	0	150	50	1805	50	1930	39218
GENESEE	46.8	1092.0	0	0	125	50	1800	50	1920	87048
GRATIOT	40.8	751.0	0	0	150	50	1805	50	1930	76194
HURON	1.5	27.0	0	0	175	50	1810	50	1950	2820
LAPEER	1.0	22.0	0	0	150	50	1805	50	1930	1868
MIDLAND	30.3	466.3	0	0	150	50	1805	50	1930	56585
SAGINAW	203.7	3841.0	0	0	150	50	1805	50	1930	380410
SHIAWASSEE	56.0	1257.6	0	0	150	50	1805	50	1930	104580
TUSCOLA	124.4	2393.0	0	0	150	50	1805	50	1930	232317
TOTAL	615.6	12000.4								1148873

Table XII (Cont.)

IRRIGATION CAPITAL COST

COUNTY	USABLE AGRICULTURE LAND (1000 ACR)	TOTAL WATER APPLIED (ACR-IN/YR) (THOUSANDS)	CENTER PIVOT (AVERAGE FARM SIZE = 400 ACRES) AREA (%)	CENTER PIVOT COST PER ACRE ($1000)	FIXED SET AVERAGE FARM SIZE (ACRES)	FIXED SET RATE = 0.1 IN/HR AREA (%)	FIXED SET RATE = 0.1 IN/HR COST PER ACRE ($/ACRE)	FIXED SET RATE = 0.2 IN/HR AREA (%)	FIXED SET RATE = 0.2 IN/HR COST PER ACRE ($/ACRE)	IRRIGATION METHOD TOTAL COST ($1000)
ZONE 6										
LAPEER	34.0	837.0	0	0	150	50	1805	50	1930	63495
MACOMB	26.8	721.0	0	0	100	50	1800	50	1905	49647
SANILAC	134.0	3405.0	0	0	175	50	1810	50	1950	251920
ST. CLAIR	65.5	1356.6	0	0	125	50	1800	50	1920	121830
TOTAL	260.3	6319.6								486892
ZONE 7										
ST. CLAIR	13.6	355.4	15	392	125	70	1800	15	1920	21852
TOTAL	13.6	355.4								21852
ZONE 9										
CLINTON	52.9	1270.3	2	392	145	48	1805	50	1930	97296
EATON	49.7	1338.0	0	0	145	50	1805	50	1930	92815
INGHAM	41.7	1111.0	5	392	165	30	1810	65	1940	76044
JACKSON	3.4	114.0	10	392	165	10	1810	80	1940	6025
LIVINGSTON	1.6	59.5	10	392	160	0	0	90	1940	2856
SHIAWASSEE	38.6	1001.6	2	392	150	48	1805	50	1930	70995
TOTAL	187.9	4894.4								346031
ZONE 10										
GENESEE	15.0	227.0	0	0	125	100	1800	0	0	27000
INGHAM	47.0	1182.0	0	0	165	50	1810	50	1940	88125
LIVINGSTON	28.0	714.0	0	0	160	50	1810	50	1940	52500
SHIAWASSEE	14.0	314.4	0	0	150	50	1805	50	1930	26145
TOTAL	104.0	2437.4								193770
ZONE 11										
GENESEE	20.7	531.0	0	0	125	50	1800	50	1920	38502
LAPEER	38.9	1222.5	15	392	145	20	1805	65	1930	65130
LIVINGSTON	58.0	1629.0	2	392	160	40	1810	58	1940	107708
OAKLAND	7.0	179.2	0	0	115	50	1800	50	1910	12985
SHIAWASSEE	1.6	36.4	0	0	150	50	1805	50	1930	2988
TOTAL	126.2	3598.1								227314
ZONE 12										
LAPEER	7.0	239.5	10	392	145	0	0	90	1930	12433
LIVINGSTON	5.9	226.5	15	392	160	0	0	85	1940	10076
MACOMB	48.2	784.0	0	0	95	60	1800	40	1900	88688
OAKLAND	34.6	1162.0	10	392	115	30	1800	60	1910	59692
WAYNE	0.8	29.0	10	392	80	0	0	90	1900	1399
TOTAL	96.5	2441.0								172289

Table XII (Cont.)

IRRIGATION CAPITAL COST

COUNTY	USABLE AGRICULTURE LAND (1000 ACR)	TOTAL WATER APPLIED (ACR-IN/YR) (THOUSANDS)	CENTER PIVOT (AVERAGE FARM SIZE = 400 ACRES) AREA (%)	CENTER PIVOT COST PER ACRE ($1000)	FIXED SET AVERAGE FARM SIZE (ACRES)	FIXED SET RATE = 0.1 IN/HR AREA (%)	RATE = 0.1 IN/HR COST PER ACRE ($/ACRE)	RATE = 0.2 IN/HR AREA (%)	RATE = 0.2 IN/HR COST PER ACRE ($/ACRE)	IRRIGATION METHOD TOTAL COST ($1000)
ZONE 13										
EATON	0.8	32.0	10	392	145	0	0	90	1930	1421
HILLSDALE	108.0	3469.0	5	392	140	25	1800	70	1930	196625
INGHAM	15.0	574.0	10	392	165	0	0	90	1940	26778
JACKSON	77.3	3013.0	10	392	165	0	0	90	1940	137996
LENAWEE	3.5	109.0	0	0	160	50	1810	50	1940	6563
TOTAL	204.6	7197.0								369382
ZONE 14										
HILLSDALE	34.4	332.0	0	0	140	100	1800	0	0	61920
LENAWEE	79.2	810.0	0	0	160	95	1810	5	1940	143867
OAKLAND	3.0	76.8	0	0	115	50	1800	50	1910	5565
WASHTENAW	73.0	2007.5	5	392	155	40	1810	55	1935	131973
WAYNE	0.4	9.7	0	0	80	50	1800	50	1900	740
TOTAL	190.0	3236.0								344065
ZONE 16										
LENAWEE	137.3	2217.0	2	392	160	70	1810	28	1940	249617
MONROE	133.0	3323.0	10	392	125	40	1800	50	1920	228654
WASHTENAW	39.5	1103.5	5	392	150	30	1805	65	1930	71716
WAYNE	20.6	596.0	5	392	80	20	1800	75	1900	37175
TOTAL	330.4	7239.5								587161

Table XIII

DISTRIBUTION, COLLECTION AND ADMINISTRATION CAPITAL COST

COUNTY	USABLE AGRICULT LAND (1000 ACRES)	WATER APPLIED (1000 ACR-IN /YR)	SYSTEM SIZE (1000 ACRES)	DISTRIBUTION SYSTEM: MAINS	DISTRIBUTION SYSTEM: CAPACITY (IN/WK)	DISTRIBUTION SYSTEM: COST PER ACRE ($/ACR)	DISTRIBUTION SYSTEM: TOTAL COST ($1000)	COLLECTION SYSTEM: MAINS	COLLECTION SYSTEM: SOIL PER. (IN/HR)	COLLECTION SYSTEM: COST PER ACRE ($/ACR)	COLLECTION SYSTEM: TOTAL COST ($1000)	ADMINISTRATION COST ($1000)
ZONE 1												
ARENAC	62.8	1299.5	86.1	CANAL	1.43	350	21980	CANAL	0.60	610	38308	6118
BAY	23.3	447.2	86.1	CANAL	1.43	350	8155	CANAL	0.60	610	14213	2248
GLADWIN	38.6	846.0	38.6	CANAL	1.50	270	10422	CANAL	0.50	610	23546	3740
MIDLAND	34.6	889.7	34.6	CANAL	1.50	260	8996	CANAL	0.75	580	20068	3150
TOTAL	159.3	3482.4					49553				96135	15257
ZONE 2												
HURON	283.0	4972.0	283.0	CANAL	1.25	610	172630	CANAL	0.20	740	209420	31975
LAPEER	1.0	22.0	86.0	PIPE	1.49	540	540	PIPE	0.74	960	960	118
SANILAC	101.3	2386.0	112.5	CANAL	1.25	380	38494	CANAL	0.20	720	72936	10567
ST. CLAIR	11.2	217.0	112.5	CANAL	1.25	380	4256	CANAL	0.20	720	8064	1163
TUSCOLA	85.0	2105.0	86.0	PIPE	1.49	540	45900	PIPE	0.74	960	81600	9967
TOTAL	481.5	9702.0					261820				372980	53790
ZONE 3												
CLINTON	83.2	1544.7	83.2	CANAL	1.25	330	27456	PIPE	0.20	1080	89856	9565
GRATIOT	136.0	2945.0	144.0	CANAL	1.25	420	57120	PIPE	0.20	1140	155040	16355
MIDLAND	8.0	149.0	144.0	CANAL	1.25	420	3360	PIPE	0.20	1140	9120	962
TOTAL	227.2	4638.7					87936				254016	26881
ZONE 4												
ARENAC	12.4	169.5	90.1	CANAL	1.25	340	4216	CANAL	0.20	715	8866	1276
BAY	77.7	1445.0	90.1	CANAL	1.25	340	26418	CANAL	0.20	715	55556	7947
CLINTON	21.0	536.0	112.7	CANAL	1.25	380	7980	CANAL	0.20	720	15120	2188
GENESEE	46.8	1092.0	109.0	CANAL	1.25	370	17316	CANAL	0.20	720	33696	4847
GRATIOT	40.8	751.0	112.7	CANAL	1.25	380	15504	CANAL	0.20	720	29376	4248
HURON	1.5	27.0	125.9	PIPE	1.25	570	855	PIPE	0.20	1130	1695	188
LAPEER	1.0	22.0	109.0	CANAL	1.25	370	370	CANAL	0.20	720	720	104
MIDLAND	30.3	466.3	81.2	CANAL	1.25	320	9696	CANAL	0.20	712	21574	3081
SAGINAW 25%	50.9	960.2	81.2	CANAL	1.25	320	16288	CANAL	0.20	712	36241	5178
SAGINAW 25%	50.9	960.3	112.7	CANAL	1.25	380	19342	CANAL	0.20	720	36648	5300
SAGINAW 20%	40.7	768.2	96.7	CANAL	1.25	350	14245	CANAL	0.20	718	29223	4192
SAGINAW 30%	61.2	1152.3	109.0	CANAL	1.25	370	22644	CANAL	0.20	720	44064	6351
SAGINAW T	203.7	3841.0					72519				146175	21020
SHIAWASSEE	56.0	1257.6	96.7	CANAL	1.25	350	19600	CANAL	0.20	718	40208	5771
TUSCOLA	124.4	2393.0	125.9	PIPE	1.25	570	70908	PIPE	0.20	1130	140572	15565
TOTAL	615.6	12000.4					245382				493558	66235

Table XIII (Cont.)

DISTRIBUTION, COLLECTION AND ADMINISTRATION CAPITAL COST

COUNTY	USABLE AGRICULT LAND (1000 ACRES)	WATER APPLIED (1000 ACR-IN /YR)	DISTRIBUTION SYSTEM: SYSTEM SIZE (1000 ACRES)	DISTRIBUTION SYSTEM: MAINS	DISTRIBUTION SYSTEM: CAPACITY (IN/WK)	DISTRIBUTION SYSTEM: COST PER ACRE ($/ACR)	DISTRIBUTION SYSTEM: TOTAL COST ($1000)	COLLECTION SYSTEM: MAINS	COLLECTION SYSTEM: SOIL PER. (IN/HR)	COLLECTION SYSTEM: COST PER ACRE ($/ACR)	COLLECTION SYSTEM: TOTAL COST ($1000)	ADMINISTRATION COST ($1000)
ZONE 6												
LAPEER 50%	17.0	418.5	151.0	CANAL	1.25	430	7310	CANAL	0.20	726	12342	1805
LAPEER 50%	17.0	418.5	82.5	CANAL	1.25	340	5780	CANAL	0.20	714	12138	1744
LAPEER T	34.0	837.0					13090				24480	3549
MACOMB	26.8	721.0	26.8	CANAL	1.25	230	6164	CANAL	0.20	692	18546	2612
SANILAC	134.0	3405.0	151.0	CANAL	1.25	430	57620	CANAL	0.20	726	97284	14285
ST. CLAIR	65.5	1356.6	82.5	CANAL	1.25	340	22270	CANAL	0.20	714	46767	6699
TOTAL	260.3	6319.6					99144				187077	27144
ZONE 7												
ST. CLAIR	13.6	355.4	13.6	CANAL	1.50	200	2720	CANAL	1.50	520	7072	1112
TOTAL	13.6	355.4					2720				7072	1112
ZONE 9												
CLINTON	52.9	1270.3	91.5	CANAL	1.25	340	17986	CANAL	0.24	700	37030	5348
EATON	49.7	1338.0	49.7	CANAL	1.25	270	13419	PIPE	0.20	1025	50943	5519
INGHAM	41.7	1111.0	46.7	CANAL	1.50	290	12093	PIPE	0.31	990	41283	4545
JACKSON	3.4	114.0	46.7	CANAL	1.50	290	986	PIPE	0.31	990	3366	365
LIVINGSTON	1.6	59.5	46.7	CANAL	1.50	290	464	PIPE	0.31	990	1584	172
SHIAWASSEE	38.6	1001.6	91.5	CANAL	1.25	340	13124	CANAL	0.24	700	27020	3903
TOTAL	187.9	4894.4					58072				161226	19852
ZONE 10												
GENESEE	15.0	227.0	29.0	PIPE	1.12	330	4950	PIPE	0.20	961	14415	1626
INGHAM	47.0	1182.0	47.0	CANAL	1.25	260	12220	PIPE	0.20	1015	47705	5198
LIVINGSTON	28.0	714.0	28.0	CANAL	1.25	230	6440	CANAL	0.20	692	19376	2751
SHIAWASSEE	14.0	314.4	29.0	PIPE	1.12	330	4620	PIPE	0.20	961	13454	1552
TOTAL	104.0	2437.4					28230				94950	11126
ZONE 11												
GENESEE	20.7	531.0	87.3	PIPE	1.41	520	10764	PIPE	0.26	1075	22253	2510
LAPEER	38.9	1222.5	38.9	PIPE	1.75	460	17894	PIPE	0.50	915	35594	4168
LIVINGSTON	58.0	1629.0	87.3	PIPE	1.41	520	30160	PIPE	0.26	1075	62350	7030
OAKLAND	7.0	179.2	87.3	PIPE	1.41	520	3640	PIPE	0.26	1075	7525	848
SHIAWASSEE	1.6	36.4	87.3	PIPE	1.41	520	832	PIPE	0.26	1075	1720	194
TOTAL	126.2	3598.1					63290				129441	14750

Table XIII (Cont.)

DISTRIBUTION, COLLECTION AND ADMINISTRATION CAPITAL COST

COUNTY	USABLE AGRICULT LAND (1000 ACRES)	WATER APPLIED (1000 ACR-IN /YR)	SYSTEM SIZE (1000 ACRES)	DISTRIBUTION SYSTEM: MAINS	DISTRIBUTION SYSTEM: CAPACITY (IN/WK)	DISTRIBUTION SYSTEM: COST PER ACRE ($/ACR)	DISTRIBUTION SYSTEM: TOTAL COST ($1000)	COLLECTION SYSTEM: MAINS	COLLECTION SYSTEM: SOIL PER. (IN/HR)	COLLECTION SYSTEM: COST PER ACRE ($/ACR)	COLLECTION SYSTEM: TOTAL COST ($1000)	ADMINISTRATION COST ($1000)
ZONE 12												
LAPEER	7.0	239.5	41.6	PIPE	1.54	442	3094	PIPE	0.41	947	6629	779
LIVINGSTON	5.9	226.5	5.9	CANAL	2.00	162	956	CANAL	0.75	560	3304	505
MACUMB	48.2	784.0	48.2	CANAL	1.25	265	12773	CANAL	0.20	704	33933	4749
OAKLAND	34.6	1162.0	41.6	PIPE	1.54	442	15293	PIPE	0.41	947	32766	3787
WAYNE	0.8	29.0	0.8	CANAL	1.75	80	64	CANAL	0.50	540	432	67
TOTAL	96.5	2441.0					32180				77064	9886
ZONE 13												
EATON	0.8	32.0	93.1	CANAL	2.00	445	356	PIPE	0.75	987	790	90
HILLSDALE	108.0	3469.0	111.5	PIPE	1.73	662	71496	PIPE	0.49	1038	112104	13355
INGHAM	15.0	574.0	93.1	CANAL	2.00	445	6675	PIPE	0.75	987	14805	1697
JACKSON	77.3	3013.0	93.1	CANAL	2.00	445	34399	PIPE	0.75	987	76295	8745
LENAWEE	3.5	109.0	111.5	PIPE	1.73	662	2317	PIPE	0.49	1038	3633	439
TOTAL	204.6	7197.0					115243				207627	24326
ZONE 14												
HILLSDALE	34.4	332.0	34.4	PIPE	1.00	325	11180	PIPE	0.20	982	33781	3745
LENAWEE	79.2	810.0	79.2	PIPE	1.00	420	33264	PIPE	0.20	1075	85140	9190
OAKLAND	3.0	76.8	76.4	CANAL	1.48	345	1035	CANAL	0.29	685	2055	304
WASHTENAW	73.0	2007.5	76.4	CANAL	1.48	345	25185	CANAL	0.29	685	50005	7278
WAYNE	0.4	9.7	76.4	CANAL	1.48	345	138	CANAL	0.29	685	274	40
TOTAL	190.0	3236.0					70802				171255	20558
ZONE 16												
LENAWEE	137.3	2217.0	270.3	CANAL	1.37	598	82105	CANAL	0.44	668	91716	14850
MONROE	133.0	3323.0	270.3	CANAL	1.37	598	79534	CANAL	0.44	668	88844	13941
WASHTENAW	39.5	1103.5	60.1	CANAL	1.58	338	13351	CANAL	0.83	580	22910	3794
WAYNE	20.6	596.0	60.1	CANAL	1.58	338	6963	CANAL	0.83	580	11948	1971
TOTAL	330.4	7239.5					181953				215418	34556

Table XIV

OPERATION AND MAINTENANCE COSTS PER YEAR

(THOUSANDS OF DOLLARS)

	CENTER PIVOT MAINT SUPPLY AND REPLAC	CENTER PIVOT LABOR	CENTER PIVOT ENERGY	FIXED SET MAINT SUPPLY AND REPLAC	FIXED SET LABOR	DISTRIBUTION SYSTEM MAINT SUPPLY AND REPLAC	DISTRIBUTION SYSTEM LABOR	DISTRIBUTION SYSTEM ENERGY	COLLECTION SYSTEM MAINT SUPPLY AND REPLAC	COLLECTION SYSTEM LABOR	COLLECTION SYSTEM ENERGY	ADMIN O & M	TOTAL
ZONE 1													
ARENAC	21	51	4	3600	966	270	427	363	647	251	43	628	7271
BAY	8	19	2	1400	359	100	158	125	240	93	15	230	2748
GLADWIN	0	0	0	2486	625	135	262	236	398	154	28	384	4710
MIDLAND	23	56	5	1821	504	117	235	248	339	138	29	326	3842
TOTAL	52	126	10	9307	2455	623	1083	971	1625	637	115	1568	18570
ZONE 2													
HURON	19	46	4	17795	4539	1864	1924	1387	3539	1132	164	3258	35671
LAPEER	0	0	0	64	16	6	7	7	18	4	4	12	137
SANILAC	7	16	1	6370	1625	462	689	666	1233	405	79	1066	12637
ST. CLAIR	0	0	0	714	181	51	76	61	136	45	7	119	1390
TUSCOLA	28	69	6	4533	1308	500	578	690	1518	340	345	1022	10938
TOTAL	54	131	11	29476	7669	2883	3274	2811	6443	1926	599	5497	60773
ZONE 3													
CLINTON	0	0	0	5327	1348	338	566	431	1671	333	253	975	11241
GRATIOT	0	0	0	8707	2203	668	925	822	2884	544	483	1671	18907
MIDLAND	0	0	0	512	130	39	54	42	170	32	24	98	1101
TOTAL	0	0	0	14546	3681	1045	1545	1294	4725	909	761	2744	31249
ZONE 4													
ARENAC	0	0	0	799	201	51	84	47	150	50	6	130	1517
BAY	0	0	0	4956	1259	322	528	403	939	311	48	812	9577
CLINTON	0	0	0	1344	340	96	143	150	256	84	18	225	2655
GENESEE	0	0	0	2985	758	208	318	305	569	187	36	498	5864
GRATIOT	0	0	0	2612	661	186	277	210	496	163	25	434	5064
HURON	0	0	0	97	24	9	10	9	32	6	4	19	210
LAPEER	0	0	0	64	16	4	7	6	12	4	1	11	125
MIDLAND	0	0	0	1940	491	119	206	130	365	121	15	314	3700
SAGINAW T	0	0	0	13041	3300	87[illegible]	1385	1071	2470	815	127	2148	25233
SHIAWASSEE	0	0	0	3585	907	237	381	351	680	224	42	592	6998
TUSCOLA	0	0	0	7964	2015	766	846	785	2615	498	392	1586	17466
TOTAL	0	0	0	39387	9972	2875	4186	3466	8582	2462	712	6768	78410
ZONE 6													
LAPEER T	0	0	0	2177	551	157	231	233	414	136	28	365	4291
MACOMB	0	0	0	1704	434	81	182	201	313	107	24	270	3317
SANILAC	0	0	0	8630	2171	674	911	950	1644	536	112	1470	17098
ST. CLAIR	0	0	0	4178	1061	274	445	378	790	262	45	686	8120
TOTAL	0	0	0	16688	4217	1186	1770	1763	3161	1041	208	2791	32825

Table XIV (Cont.)

OPERATION AND MAINTENANCE COSTS PER YEAR

	(THOUSANDS OF DOLLARS) CENTER PIVOT			FIXED SET		DISTRIBUTION SYSTEM			COLLECTION SYSTEM				
	MAINT SUPPLY AND REPLAC	LABOR	ENERGY	MAINT SUPPLY AND REPLAC	LABOR	MAINT SUPPLY AND REPLAC	LABOR	ENERGY	MAINT SUPPLY AND REPLAC	LABOR	ENERGY	ADMIN O & M	TOTAL
ZONE 7													
ST. CLAIR	14	33	3	812	187	38	92	99	120	54	12	115	1579
TOTAL	14	33	3	812	187	38	92	99	120	54	12	115	1579
ZONE 9													
CLINTON	7	17	1	3308	840	219	360	354	626	212	42	550	6537
EATON	0	0	0	3182	805	172	338	373	948	199	219	568	6804
INGHAM	14	34	3	2401	642	155	284	310	768	167	182	468	5425
JACKSON	2	6	0	173	50	13	23	32	63	14	19	38	431
LIVINGSTON	1	3	0	78	23	6	11	17	29	6	10	18	202
SHIAWASSEE	5	13	1	2414	613	160	262	279	457	154	33	402	4794
TOTAL	29	71	6	11556	2972	724	1277	1365	2890	752	505	2044	24192
ZONE 10													
GENESEE	0	0	0	1107	243	56	102	74	268	60	37	165	2113
INGHAM	0	0	0	3020	761	156	320	330	887	188	194	534	6391
LIVINGSTON	0	0	0	1799	454	85	190	199	327	112	24	284	3474
SHIAWASSEE	0	0	0	896	227	52	95	103	250	56	52	159	1890
TOTAL	0	0	0	6823	1685	350	707	706	1733	416	306	1142	13868
ZONE 11													
GENESEE	0	0	0	1320	335	116	141	174	414	83	87	257	2928
LAPEER	39	95	8	1942	536	200	265	401	662	156	200	432	4934
LIVINGSTON	8	19	2	3549	921	326	394	534	1160	232	267	723	8133
OAKLAND	0	0	0	445	113	39	48	59	140	28	29	87	989
SHIAWASSEE	0	0	0	102	26	9	11	12	32	6	6	20	224
TOTAL	47	113	9	7359	1931	691	858	1180	2407	505	590	1518	17207
ZONE 12													
LAPEER	5	11	1	340	102	34	48	79	123	28	39	81	891
LIVINGSTON	6	14	1	272	81	14	40	63	56	24	7	53	632
MACOMB	0	0	0	3160	781	163	328	219	573	193	26	484	5927
OAKLAND	23	56	5	1876	504	170	235	381	609	138	191	393	4581
WAYNE	1	1	0	38	12	1	5	8	7	3	1	7	84
TOTAL	34	83	7	5687	1480	382	656	749	1369	386	264	1018	12115
ZONE 13													
EATON	1	1	0	39	12	4	5	9	15	3	5	9	103
HILLSDALE	36	87	7	6078	1662	772	734	1138	2085	432	569	1378	14978
INGHAM	10	24	2	733	219	81	102	160	275	60	94	177	1938
JACKSON	52	125	10	3779	1127	420	526	841	1419	309	494	911	10012
LENAWEE	0	0	0	225	57	25	24	36	68	14	18	45	511
TOTAL	98	238	19	10854	3076	1302	1391	2183	3862	818	1180	2520	27542

Table XIV (Cont.)

OPERATION AND MAINTENANCE COSTS PER YEAR

(THOUSANDS OF DOLLARS)

	CENTER PIVOT MAINT SUPPLY AND REPLAC	CENTER PIVOT LABOR	CENTER PIVOT ENERGY	FIXED SET MAINT SUPPLY AND REPLAC	FIXED SET LABOR	DISTRIBUTION SYSTEM MAINT SUPPLY AND REPLAC	DISTRIBUTION SYSTEM LABOR	DISTRIBUTION SYSTEM ENERGY	COLLECTION SYSTEM MAINT SUPPLY AND REPLAC	COLLECTION SYSTEM LABOR	COLLECTION SYSTEM ENERGY	ADMIN O & M	TOTAL
ZONE 14													
HILLSDALE	0	0	0	2539	557	125	234	109	628	138	54	378	4763
LENAWEE	0	0	0	5799	1283	363	539	266	1584	317	133	929	11210
OAKLAND	0	0	0	191	49	13	20	21	35	12	3	31	374
WASHTENAW	24	59	5	4342	1123	310	496	560	845	292	66	752	8875
WAYNE	0	0	0	25	6	2	3	3	5	2	0	4	49
TOTAL	24	59	5	12896	3019	812	1292	959	3096	760	256	2095	25272
ZONE 16													
LENAWEE	18	44	4	9221	2180	887	934	619	1550	549	73	1512	17590
MONROE	89	215	18	7501	1939	859	904	927	1501	532	110	1434	16030
WASHTENAW	13	32	3	2264	608	168	269	308	387	158	36	393	4639
WAYNE	7	17	1	1126	317	88	140	166	202	82	20	204	2370
TOTAL	127	308	25	20112	5044	2002	2247	2020	3640	1322	239	3543	40628

Table XV

COST TOTALS

	CAPITAL ($1000)	CAPITAL RECOVERY ($1000)	O & M ($1000)	TOTAL ANNUAL COST ($1000)	COST PER MG OF WATER APPLIED: CAPITAL ($/MG)	ANNUAL ($/MG)
ZONE 1						
ARENAC	180426	10656	7271	17927	5113	508
BAY	66314	3916	2748	6665	5461	549
GLADWIN	110276	6513	4710	11222	4800	489
MIDLAND	92805	5481	3842	9323	3841	386
TOTAL	449821	26566	18570	45137	4757	477
ZONE 2						
HURON	943637	55731	35671	91402	6989	677
LAPEER	3486	206	137	343	5835	574
SANILAC	311572	18401	12637	31038	4809	479
ST. CLAIR	34315	2027	1390	3417	5824	580
TUSCOLA	293918	17359	10938	28297	5142	495
TOTAL	1586927	93724	60773	154497	6024	586
ZONE 3						
CLINTON	282253	16670	11241	27911	6729	665
GRATIOT	482495	28496	18907	47403	6034	593
MIDLAND	28382	1676	1101	2777	7015	686
TOTAL	793129	46842	31249	78091	6297	620
ZONE 4						
ARENAC	37670	2225	1517	3741	8184	813
BAY	234442	13846	9577	23424	5975	597
CLINTON	64506	3810	2655	6465	4432	444
GENESEE	142907	8440	5864	14304	4819	482
GRATIOT	125322	7401	5064	12465	6145	611
HURON	5558	328	210	538	7581	734
LAPEER	3061	181	125	306	5124	512
MIDLAND	90936	5371	3700	9071	7182	716
SAGINAW T	620124	36624	25233	61858	5946	593
SHIAWASSEE	170159	10050	6998	17048	4983	499
TUSCOLA	459362	27130	17466	44596	7069	686
TOTAL	1954047	115405	78410	193815	5997	595
ZONE 6						
LAPEER T	104614	6178	4291	10469	4603	461
MACOMB	76969	4546	3317	7862	3931	402
SANILAC	421109	24871	17098	41969	4555	454
ST. CLAIR	197566	11668	8120	19788	5363	537
TOTAL	800257	47263	32825	80088	4663	467
ZONE 7						
ST. CLAIR	32757	1935	1579	3513	3394	364
TOTAL	32757	1935	1579	3513	3394	364

Table XV (Cont.)

COST TOTALS

	CAPITAL ($1000)	CAPITAL RECOVERY ($1000)	O & M ($1000)	TOTAL ANNUAL COST ($1000)	COST PER MG OF WATER APPLIED CAPITAL ($/MG)	ANNUAL ($/MG)
ZONE 9						
CLINTON	157660	9311	6537	15848	4571	459
EATON	162695	9609	6804	16412	4478	452
INGHAM	133965	7912	5425	13337	4441	442
JACKSON	10742	634	431	1065	3470	344
LIVINGSTON	5077	300	202	502	3142	311
SHIAWASSEE	115042	6794	4794	11588	4230	426
TOTAL	585181	34560	24192	58752	4403	442
ZONE 10						
GENESEE	47991	2834	2113	4947	7786	803
INGHAM	153248	9051	6391	15441	4775	481
LIVINGSTON	81067	4788	3474	8262	4181	426
SHIAWASSEE	45771	2703	1890	4593	5361	538
TOTAL	328076	19376	13868	33244	4957	502
ZONE 11						
GENESEE	74029	4372	2928	7300	5134	506
LAPEER	122786	7252	4934	12186	3699	367
LIVINGSTON	207248	12240	8133	20373	4685	461
OAKLAND	24998	1476	989	2465	5137	507
SHIAWASSEE	5734	339	224	562	5802	569
TOTAL	434794	25679	17207	42886	4450	439
ZONE 12						
LAPEER	22935	1355	891	2245	3527	345
LIVINGSTON	14841	876	632	1508	2413	245
MACOMB	140143	8277	5927	14204	6583	667
OAKLAND	111538	6587	4581	11169	3535	354
WAYNE	1962	116	84	200	2492	254
TOTAL	291419	17211	12115	29326	4397	442
ZONE 13						
EATON	2657	157	103	260	3057	299
HILLSDALE	393579	23245	14978	38223	4178	406
INGHAM	49955	2950	1938	4888	3205	314
JACKSON	257434	15204	10012	25216	3147	308
LENAWEE	12952	765	511	1275	4376	431
TOTAL	716577	42321	27542	69862	3667	357

Table XV (Cont.)

COST TOTALS

	CAPITAL ($1000)	CAPITAL RECOVERY ($1000)	O & M ($1000)	TOTAL ANNUAL COST ($1000)	COST PER MG OF WATER APPLIED CAPITAL ($/MG)	COST PER MG OF WATER APPLIED ANNUAL ($/MG)
ZONE 14						
HILLSDALE	110626	6534	4763	11296	12271	1253
LENAWEE	271461	16032	11210	27243	12342	1239
OAKLAND	8959	529	374	904	4296	433
WASHTENAW	214441	12665	8875	21540	3934	395
WAYNE	1192	70	49	120	4527	455
TOTAL	606679	35830	25272	61102	6904	695
ZONE 16						
LENAWEE	438289	25885	17590	43475	7280	722
MONROE	410973	24272	16030	40302	4555	447
WASHTENAW	111771	6601	4639	11240	3730	375
WAYNE	58057	3429	2370	5799	3587	358
TOTAL	1019089	60187	40628	100815	5184	513

Table XVI

COST TOTALS FOR 7% AND 10% INTEREST RATES

COUNTY	INTEREST RATE = 7%: CAPITAL ($1000)	CAPITAL RECOVERY ($1000)	O & M ($1000)	TOTAL ANNUAL COST ($1000)	COST PER MG OF WATER APPLIED: CAPITAL ($/MG)	ANNUAL ($/MG)	INTEREST RATE = 10%: CAPITAL RECOVERY ($1000)	O & M ($1000)	TOTAL ANNUAL COST ($1000)	COST PER MG OF WATER APPLIED: CAPITAL ($/MG)	ANNUAL ($/MG)
ZONE 1											
ARENAC	180426	13072	7178	20250	5113	574	18203	7033	25236	5113	715
BAY	66314	4804	2713	7517	5461	619	6690	2658	9349	5461	770
GLADWIN	110276	7990	4649	12639	4800	550	11126	4555	15681	4800	683
MIDLAND	92805	6724	3793	10516	3841	435	9363	3716	13079	3841	541
TOTAL	449821	32589	18333	50922	4757	539	45382	17963	63345	4757	670
ZONE 2											
HURON	943637	68367	35214	103580	6989	767	95204	34504	129708	6989	961
LAPEER	3486	253	136	388	5835	649	352	133	484	5835	811
SANILAC	311572	22573	12475	35049	4809	541	31434	12224	43658	4809	674
ST. CLAIR	34315	2486	1373	3859	5824	655	3462	1345	4807	5824	816
TUSCOLA	293918	21294	10798	32092	5142	561	29653	10580	40234	5142	704
TOTAL	1586927	114973	59995	174968	6024	664	160105	58786	218890	6024	831
ZONE 3											
CLINTON	282253	20449	11097	31547	6729	752	28476	10874	39350	6729	938
GRATIOT	482495	34957	18665	53621	6034	671	48679	18288	66967	6034	837
MIDLAND	28382	2056	1087	3143	7015	777	2863	1065	3928	7015	971
TOTAL	793129	57462	30849	88311	6297	701	80019	30227	110245	6297	875
ZONE 4											
ARENAC	37670	2729	1497	4226	8184	918	3801	1467	5268	8184	1144
BAY	234442	16985	9455	26440	5975	674	23653	9264	32917	5975	839
CLINTON	64506	4673	2621	7294	4432	501	6508	2568	9076	4432	624
GENESEE	142907	10354	5789	16142	4819	544	14418	5672	20090	4819	678
GRATIOT	125322	9080	4999	14079	6145	690	12644	4898	17542	6145	860
HURON	5558	403	207	610	7581	832	561	203	764	7581	1042
LAPEER	3061	222	123	345	5124	577	309	121	430	5124	719
MIDLAND	90936	6588	3653	10241	7182	809	9175	3579	12754	7182	1007
SAGINAW T	620124	44928	24910	69838	5946	670	62564	24408	86972	5946	834
SHIAWASSEE	170159	12328	6909	19237	4983	563	17167	6769	23937	4983	701
TUSCOLA	459362	33281	17243	50523	7069	778	46345	16895	63240	7069	973
TOTAL	1954047	141570	77406	218976	5997	672	197143	75846	272989	5997	838
ZONE 6											
LAPEER T	104614	7579	4235	11815	4603	520	10554	4150	14704	4603	647
MACOMB	76969	5576	3274	8850	3931	452	7765	3208	10973	3931	560
SANILAC	421109	30509	16879	47389	4555	513	42486	16539	59025	4555	638
ST. CLAIR	197566	14314	8016	22329	5363	606	19932	7854	27786	5363	754
TOTAL	800257	57978	32404	90383	4663	527	80738	31751	112489	4663	656

Table XVI (Cont.)

COST TOTALS FOR 7% AND 10% INTEREST RATES

COUNTY	CAPITAL ($1000)	INTEREST RATE = 7%: CAPITAL RECOVERY ($1000)	O & M ($1000)	TOTAL ANNUAL COST ($1000)	COST PER MG OF WATER APPLIED: CAPITAL ($/MG)	ANNUAL ($/MG)	INTEREST RATE = 10%: CAPITAL RECOVERY ($1000)	O & M ($1000)	TOTAL ANNUAL COST ($1000)	COST PER MG OF WATER APPLIED: CAPITAL ($/MG)	ANNUAL ($/MG)
ZONE 7											
ST. CLAIR	32757	2373	1558	3932	3394	407	3305	1527	4832	3394	501
TOTAL	32757	2373	1558	3932	3394	407	3305	1527	4832	3394	501
ZONE 9											
CLINTON	157660	11422	6453	17875	4571	518	15906	6323	22229	4571	644
EATON	162695	11787	6717	18504	4478	509	16414	6581	22996	4478	633
INGHAM	133965	9706	5356	15062	4441	499	13516	5248	18764	4441	622
JACKSON	10742	778	425	1203	3470	389	1084	417	1500	3470	485
LIVINGSTON	5077	368	199	567	3142	351	512	195	707	3142	438
SHIAWASSEE	115042	8335	4732	13067	4230	480	11607	4637	16244	4230	597
TOTAL	585181	42396	23882	66278	4403	499	59039	23401	82439	4403	620
ZONE 10											
GENESEE	47991	3477	2086	5563	7786	902	4842	2044	6885	7786	1117
INGHAM	153248	11103	6309	17412	4775	542	15461	6182	21643	4775	674
LIVINGSTON	81067	5873	3430	9303	4181	480	8179	3361	11539	4181	595
SHIAWASSEE	45771	3316	1866	5182	5361	607	4618	1828	6446	5361	755
TOTAL	328076	23769	13690	37459	4957	566	33099	13414	46514	4957	703
ZONE 11											
GENESEE	74029	5363	2890	8253	5134	572	7469	2832	10300	5134	714
LAPEER	122786	8896	4871	13767	3699	415	12388	4773	17161	3699	517
LIVINGSTON	207248	15015	8029	23044	4685	521	20909	7867	28777	4685	651
OAKLAND	24998	1811	976	2787	5137	573	2522	956	3478	5137	715
SHIAWASSEE	5734	415	221	636	5802	644	579	216	795	5802	804
TOTAL	434794	31501	16987	48487	4450	496	43866	16644	60511	4450	619
ZONE 12											
LAPEER	22935	1662	879	2541	3527	391	2314	862	3175	3527	488
LIVINGSTON	14841	1075	624	1699	2413	276	1497	611	2108	2413	343
MACOMB	140143	10153	5851	16004	6583	752	14139	5733	19872	6583	933
OAKLAND	111538	8081	4523	12603	3535	399	11253	4431	15684	3535	497
WAYNE	1962	142	83	225	2492	286	198	82	280	2492	355
TOTAL	291419	21113	11960	33073	4397	499	29401	11718	41119	4397	620
ZONE 13											
EATON	2657	192	102	294	3057	339	268	100	368	3057	423
HILLSDALE	393579	28515	14787	43301	4178	460	39708	14489	54197	4178	575
INGHAM	49955	3619	1913	5532	3205	355	5060	1874	6934	3205	444
JACKSON	257434	18651	9884	28535	3147	349	25973	9685	35657	3147	436
LENAWEE	12952	938	504	1442	4376	687	1307	494	1801	4376	[illegible]
TOTAL	716577	51916	27189	79105	3667	405	72295	26641	98936	3667	506

Table XVI (Cont.)

COST TOTALS FOR 7% AND 10% INTEREST RATES

COUNTY	CAPITAL ($1000)	INTEREST RATE = 7%: CAPITAL RECOVERY ($1000)	O & M ($1000)	TOTAL ANNUAL COST ($1000)	COST PER MG OF WATER APPLIED: CAPITAL ($/MG)	ANNUAL ($/MG)	INTEREST RATE = 10%: CAPITAL RECOVERY ($1000)	O & M ($1000)	TOTAL ANNUAL COST ($1000)	COST PER MG OF WATER APPLIED: CAPITAL ($/MG)	ANNUAL ($/MG)
ZONE 14											
HILLSDALE	110626	8015	4702	12716	12271	1411	11161	4607	15768	12271	1749
LENAWEE	271461	19667	11067	30734	12342	1397	27388	10844	38231	12342	1738
OAKLAND	8959	649	370	1019	4296	488	904	362	1266	4296	607
WASHTENAW	214441	15536	8762	24298	3934	446	21635	8585	30220	3934	554
WAYNE	1192	86	49	135	4527	513	120	48	169	4527	638
TOTAL	606679	43954	24948	68902	6904	784	61208	24445	85653	6904	975
ZONE 16											
LENAWEE	438289	31754	17364	49118	7280	816	44219	17014	61233	7280	1017
MONROE	410973	29775	15825	45599	4555	505	41463	15506	56969	4555	631
WASHTENAW	111771	8098	4579	12677	3730	423	11277	4487	15764	3730	526
WAYNE	58057	4206	2339	6545	3587	404	5857	2292	8149	3587	504
TOTAL	1019089	73833	40107	113940	5184	580	102816	39299	142115	5184	723

Table XVII

ENERGY USED PER YEAR

	THOUSANDS KW-HR USED PER YEAR			
	CENTER PIVOT	DISTRIBUTION SYSTEM	COLLECTION SYSTEM	TOTAL
ZONE 1				
ARENAC	334	28979	3431	32743
BAY	124	9973	1181	11277
GLADWIN	0	18866	2233	21099
MIDLAND	368	19840	2349	22557
TOTAL	826	77657	9193	87677
ZONE 2				
HURON	301	110876	13126	124303
LAPEER	0	579	289	867
SANILAC	108	53208	6299	59615
ST. CLAIR	0	4839	573	5412
TUSCOLA	452	55362	27618	83431
TOTAL	861	224863	47904	273627
ZONE 3				
CLINTON	0	34447	20266	54713
GRATIOT	0	65674	38638	104312
MIDLAND	0	3323	1955	5278
TOTAL	0	103443	60860	164302
ZONE 4				
ARENAC	0	3780	447	4227
BAY	0	32224	3815	36038
CLINTON	0	11953	1415	13368
GENESEE	0	24352	2883	27234
GRATIOT	0	16747	1983	18730
HURON	0	710	354	1064
LAPEER	0	491	58	549
MIDLAND	0	10398	1231	11629
SAGINAW T	0	85654	10140	95794
SHIAWASSEE	0	28044	3320	31364
TUSCOLA	0	62936	31396	94332
TOTAL	0	277288	57042	334329
ZONE 6				
LAPEER T	0	18665	2210	20874
MACOMB	0	16078	1903	17982
SANILAC	0	75932	8989	84921
ST. CLAIR	0	30252	3581	33834
TOTAL	0	140927	16684	157610
ZONE 7				
ST. CLAIR	217	7925	938	9081
TOTAL	217	7925	938	9081

Table XVII (Cont.)

ENERGY USED PER YEAR

	THOUSANDS KW-HR USED PER YEAR			
	CENTER PIVOT	DISTRIBUTION SYSTEM	COLLECTION SYSTEM	TOTAL
ZONE 9				
CLINTON	113	28328	3354	31794
EATON	0	29837	17555	47392
INGHAM	222	24775	14576	39573
JACKSON	36	2542	1496	4074
LIVINGSTON	17	1327	781	2124
SHIAWASSEE	82	22336	2644	25062
TOTAL	470	109145	40405	150019
ZONE 10				
GENESEE	0	5970	2978	8948
INGHAM	0	26359	15508	41866
LIVINGSTON	0	15922	1885	17807
SHIAWASSEE	0	8269	4125	12394
TOTAL	0	56520	24496	81015
ZONE 11				
GENESEE	0	13965	6967	20932
LAPEER	621	32152	16039	48812
LIVINGSTON	123	42843	21372	64339
OAKLAND	0	4713	2351	7064
SHIAWASSEE	0	957	478	1435
TOTAL	744	94630	47207	142581
ZONE 12				
LAPEER	74	6299	3142	9515
LIVINGSTON	94	5051	598	5743
MACOMB	0	17483	2070	19553
OAKLAND	368	30561	15245	46174
WAYNE	9	647	77	732
TOTAL	545	60040	21132	81717
ZONE 13				
EATON	9	714	420	1142
HILLSDALE	575	91235	45513	137322
INGHAM	160	12800	7531	20491
JACKSON	822	67190	39531	107543
LENAWEE	0	2867	1430	4297
TOTAL	1565	174805	94424	270794

Table XVII (Cont.)

ENERGY USED PER YEAR

	THOUSANDS KW-HR USED PER YEAR			
	CENTER PIVOT	DISTRIBUTION SYSTEM	COLLECTION SYSTEM	TOTAL
ZONE 14				
HILLSDALE	0	8732	4356	13087
LENAWEE	0	21303	10627	31930
OAKLAND	0	1713	203	1915
WASHTENAW	388	44767	5300	50455
WAYNE	0	216	26	242
TOTAL	388	76731	20511	97630
ZONE 16				
LENAWEE	292	49439	5853	55584
MONROE	1415	74103	8773	84291
WASHTENAW	210	24608	2913	27731
WAYNE	110	13291	1573	14974
TOTAL	2027	161441	19112	182579

SECTION V

BENEFITS AND DETRIMENTS

The land treatment plan developed in this report will have benefits and detriments both for farmers and society in general. This section highlights some of them without presenting detailed explanations. A detailed study on each benefit or detriment is suggested to better define its accuracy and magnitude. In some cases, such studies may indicate that items initially listed as benefits may in fact be more realistically considered a detriment and vice versa.

FARM PROFITS AND MANAGEMENT

The land treatment systems provide cooperating farmers with water for irrigation; plant nutrients, contained in the water; and subsurface drainage. During the "average year," these factors should increase crop yields and farm profits. Increases in crop yields are expected based on the experiences of Pennsylvania State University (7), Braunschweig, Germany (10) and others. The magnitude of the profit depends upon the management arrangement between the farmer and the agency possessing the wastewater. Farm profit will be minimal if the farmer pays to receive the wastewater and maximal if the agency pays the farmer to receive the wastewater.

During a drought year, wastewater application would be beneficial for increasing crop yields. This

may not be true for an extremely wet year. However, the tile drainage system, with laterals much closer than present farming practice, would be expected to remove the water and reduce crop losses such as were experienced in 1972 due to heavy fall rains.

A cooperating farmer will have to become a better farm manager. He must continue to make all the farm management decisions as in the past, in addition to receiving and applying wastewater in accordance with an irrigation schedule specified in the contractual agreement. This additional farm management responsibility could be considered a detriment, but might make the farmer a better overall manager. If forced to make wastewater applicatons on a prescribed schedule, he might be more conscious of other farm management decisions such as planting dates, selection of new seed varieties, timing of supplemental fertilizer additions, herbicide and pesticide applications, harvest dates, etc.

RURAL COMMUNITIES

The installation of distribution, irrigation, and collection systems will cause some inconveniences and irritations to various communities and farmers during construction and also to farmers after construction. During installation, construction activities might interfere with traffic flows and other activities within the community. Some loss of farm productivity will be experienced due to the physical act of installing irrigation and drainage systems. After installation, the farmer must plant and harvest crops around the irrigation equipment.

A need will exist for people to man and maintain the distribution, irrigation, and drainage systems. This manpower requirement could at least be partially satisfied locally, which should reduce unemployment. If the manpower comes from the outside, additional revenue would be brought into the community. Considerable government funds would be required to construct the vast land treatment system to treat 2.7 billion gallons of wastewater per day. This should boost the economy of rural communities.

The construction of the land treatment system should restrict urban sprawl. With an operating land treatment system, more incentive should exist to keep the land zoned agricultural. This should be a benefit to farmers and to urban planners wanting to limit urban sprawl.

In addition to irrigation land, considerable land is required for treatment lagoons, storage lagoons, reuse ponds, and sludge disposal. At best, only a portion of this land will come from prime agricultural land. The loss of this agricultural land must be considered a detriment. However, some benefits might develop such as using the storage lagoons as a source for industrial cooling water and the adjacent buffer areas as sites for solid waste disposal. Further, the water from the reuse ponds is useful for stream flow augmentation, recreational purposes, groundwater recharge, etc.

Less community disruption is expected with the use of private farms as compared with the land treat-

ment designs developed in the Phase I-Phase II Report (3), which assumed public ownership of the irrigation land. In this earlier study, land was acquired, farm families were relocated, and much of the community tax base was eroded. In this respect, the use of privately owned farm land should better benefit the rural communities.

Extensive land areas are required to treat the Southeastern Michigan wastewater. Hence, many people may be affected either favorably or unfavorably. The effect on people would be less with physical-chemical or advanced biological treatment plants. On a relative basis, these plants require only a few acres. The land treatment system requires maintenance and operation of facilities extending over hundreds of square miles. Physical-chemical or advanced biological treatment plants require maintenance and operation of relatively compact facilities.

NUTRIENT RECYCLE

Two benefits generally associated with land treatment systems are the discharging of clean water into our streams and plant nutrient recycling for farm crops. Some engineering estimates indicate land treatment will remove from the wastewater 98% of the BOD, 95% COD, 85% N, 99% P, 95% metals, 99% suspended solids, and 99% of the pathogens (11). Other treatment schemes such as advanced biological and physical-chemical methods are reportedly as effective in providing wastewater treatment. However, plant nutrients such as nitrogen, phosphorus, potassium, zinc, copper, etc. are not normally recycled and used again in food

production. Advanced biological and physical-chemical treatment either converts nutrients to sludges or destroys them. Land treatment allows the direct recycling of plant nutrients. Thus, farmers receiving wastewater will require less commercial fertilizer. This fertilizer consumes natural resources for production and creates some environmental pollution problems in their manufacture. The situation is compounded when only secondary treatment is provided. In this case, wastewater containing these nutrients is discharged directly into adjacent streams. These nutrients are not only wasted, but significantly contribute to the degradation of the stream. At the same time, local farmers are buying commercial fertilizers containing the same nutrients in the discharge from the secondary treatment plant.

NITRATE, PHOSPHORUS, HEAVY METALS, PATHOGEN, ETC.

Land treatment is sometimes related to (i) nitrate and phosphorus leakage into the groundwater, (ii) waterlogging the soil, (iii) "poisoning" the soil with heavy metals and salts, and (iv) spreading pathogenic organisms in the environment. If such were the case, then the land treatment plan developed for Southeastern Michigan would be a detriment to society, and to the farmers in particular. Several of the above factors were addressed in the Phase III Report (5) and more completely elsewhere. Hence, the above are not believed to be significant detriments, especially in a well-designed and well-operated land treatment facility. The subsequent discussion is presented to summarize and to offer further explanation.

One of the factors* governing the annual wastewater application in Southeastern Michigan is the 50-year phosphorus adsorption capacity of the receiving soil. If higher wastewater application than those suggested in the Phase III Report (5) were used, significant phosphorus leakage into the tile drainage water or groundwater would be expected in less than 50 years, especially on the more sandy soils. By matching the wastewater application with the phosphorus adsorption capacity of the soil, one could expect to have a soil rich in phosphorus at the end of 50 years. At this point, the soil must be retired from wastewater renovation. Farming could be continued, but commercial phosphorus fertilizer would not be needed for several years.

The wastewater contains nitrogen, which is expected to be largely converted to nitrate in the soil. Some denitrification will occur, but most of the nitrate is expected to be taken up by the crops. Thus, little nitrate leakage into the tile drains is expected assuming optimum crop yields and proper application of the wastewater during the growing season. In some cases as pointed out in the Phase III Report (5), additional nitrogen must be added to insure optimum crop yields.

The soil is not expected to become saturated or "waterlogged" assuming the wastewater application rates are used as specified in the Phase III Report (5), and a functional tile drainage system is installed. The

---

*The other governing factor in Southeastern Michigan is the hydraulic loading on the finer textured soils.

recommended wastewater application rates are believed conservative and in line with the ability of the soil to both infiltrate and percolate the applied wastewater. Even with these conservative application rates, a tile drainage system is necessary to prevent waterlogging the soil and to maintain aerobic conditions in the soil.

The Phase III Report (5) discusses heavy metals and salts, which are contained in the applied wastewater. Most heavy metals will be immobilized by interacting with mineral and organic colloids, most probably in the plow layer of the soil. The heavy metals have little likelihood of accumulating to dangerous levels in plants or moving into drainage in concentrations exceeding drinking water standards. One possible exception is boron. The applied boron might be toxic to some sensitive crops or the boron-adsorbing capacity of soils may be saturated after several years. Another plant nutritional problem may arise from the high concentration of iron in the wastewater. Iron accentuates deficiencies of zinc and manganese in some crops. These deficiencies are readily identified and can be corrected.

Salts have little likelihood of accumulating to a dangerous point in most soils. With the annual rainfall of about 35-40 inches and the wastewater application, the salts will be leached from the soil provided that drainage is not restricted. If drainage is restricted, some accumulation of salts are expected as pointed out in the Phase III Report (5). Evapotranspiration in the absence of deep percolation causes

salt accumulation in the soil surface horizons. Soil Management Group 1.5 (5) presents the greatest concern in this respect. Other soil management groups in Southeastern Michigan present little concern for potential salt accumulations.

Another concern is the spreading of pathogenic organisms into the environment. This concern is largely negated by the fact that the wastewater, equivalent to secondary treatment, is disinfected prior to irrigation onto the agricultural land. The quality of this irrigation water is the same as the treated wastewater commonly discharged into surface water supplies and bodies of water used for recreation, fishing, irrigation, etc. Nevertheless, some pathogenic organisms may survive disinfection. The soil system is considered a hostile environment for most pathogenic organisms. Thus, those pathogens which survive disinfection and are subsequently irrigated onto the land would be expected to have a low chance of surviving in the soil environment (6).

The APWA Research Foundation examined 100 examples of wastewater application on land for the U. S. Environmental Protection Agency. These researchers found in general chlorinated effluent enhances crop growth with no ill effects (1). In some cases, the land treatment facility at Braunschweig, Germany uses primary effluent without disinfection for crop irrigation. Reportedly, human health problems have not developed because of this practice (10). In some U. S. locales, disinfected wastewater is used to irrigate golf courses

and parks (9). Bernarde (2) suggests land treatment is far less hazardous from a communicable disease viewpoint than disposal into rivers and streams.

SECTION VI

SUMMARY AND RECOMMENDATIONS

A conceptual design was developed for land treatment of the wastewater produced in Southeastern Michigan. This design uses privately owned farmland in lieu of publicly owned land as considered earlier in the Phase I-Phase II Report [3]. Crop and soil scientists at Michigan State University made estimates and judgements on (i) soils, (ii) land use and crops, and (iii) projected application of wastewater in 25 Southeastern Michigan counties [5]. Their data serve as a basis for the land treatment design developed in this Phase IV study.

Adjacent soil association areas with similar wastewater application rates were grouped into wastewater treatment zones. The Southeastern Michigan area was divided into 17 such zones. Agricultural land usable for wastewater application is distributed throughout most zones. However, some of the identified zones were unsuitable for wastewater application because of soil considerations or large urban areas.

Design assumptions were developed for wastewater irrigation and collection on those zones possessing usable agricultural land. Briefly, these assumptions include: private farmers retain ownership and management of their farms and contract to receive wastewater. Soil and crop considerations determine the amount of

wastewater which is applied according to prescribed irrigation schedules. Each farm possesses an independent irrigation system. Wastewater is delivered in pressure pipes to the irrigation system, which is fixed-set or center-pivot sprinklers. After percolating through the soil profile, the renovated wastewater is collected by a tile drainage system, temporarily stored in a reuse pond, and finally discharged into nearby streams.

Using the above design assumptions, unit costs were developed for each component of the land treatment system. These unit costs were multiplied by the usable agricultural acreage to obtain total costs, which were tabulated by counties within each wastewater treatment zone. Eventually, entire zones and possibly county portions of some other zones will be selected to treat the wastewater produced in Southeastern Michigan. Thus, total cost for the land treatment of this wastewater can be obtained by summing the costs for the selected zones and county portions of zones. For the wastewater treatment zones, capital costs range from $3400 to $6900 and annual costs ranged from $360 to $695 per million gallons of water treated. These costs are not directly comparable with those developed in the Phase I-Phase II report because different design rationales were imposed in some cases.

The land treatment plan using privately owned farm land has several benefits and detriments for farmers and society. Among the possible benefits are (i) nutrient recycle, (ii) increased crop yields and farm

profit and (iii) renovation of wastewater. Detriments include (i) added farm management responsibilities, (ii) inconveniences and irritations for the rural community during construction, (iii) extensive land requirements for treatment and storage lagoons, etc.

In both the Phase III and IV studies, several estimates and assumptions were used to develop costs in the allotted time. These costs are believed to be of sufficient accuracy to assess land treatment and to identify viable design concepts and land areas for wastewater applications. However, further studies are recommended for developing designs and costs possessing greater accuracy. Further, a demonstration project is needed to study land treatment using privately owned farm land typical of Southeastern Michigan soils, farming, and weather conditions. This demonstration project is needed to verify under field conditions, such parameters as wastewater application rates, tile lateral spacings and depths, crop systems and yields, suitability of irrigation equipment, and labor requirements.

SECTION VII

REFERENCES

1. APWA Reporter, an editorial, Vol. 40 (May 1973).

2. Benarde, M. A., Land Disposal and Sewage Effluent: Appraisal of Human Effects of Pathogenic Organisms, Journal American Water Works Association, Vol. 65: 432-440 (1973).

3. Dow Engineering, Inc., Irrigation and Collection Facilities for Southeastern Michigan Wastewater Management Program, Contract No. DACW 35-72-C-0028, Detroit District of the U. S. Army Corps of Engineers, (November 1, 1972).

4. Ellis, B. G., Erickson, A. E., Knezek, B. P., and Wolcott, A. R., Impact of Wastewater on Soils, Technical Report No. 30, Institute of Water Research, Michigan State University (October 1972).

5. Ellis, B. G., Erickson, A. E., Knezek, B. P., Kunze, R. J., Schneider, I. F., Whiteside, E. P., Wolcott, A. R., and Cook, R. L., Land Treatment of Wastewater in Southeastern Michigan, Michigan State University (June 1973).

6. Miller, R. H., The Soil as a Biological Filter, presented at the Symposium on Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Pennsylvania State University (August 1972).

7. Parizek, R. R., Kardos, L. T., Sopper, W. E., Myers, E. A., Davis, P. E., Farrell, M. A., and Nesbitt, J. B., Wastewater Renovation and Conservation, Pennsylvania State Studies No. 23, The Pennsylvania State University (1967).

8. Schwab, D., Oklahoma State University Extension - Personal Communication (June 1973).

9. Temple University - Center for the Study of Federalism, Green Land-Clean Stream, Philadelphia, Pennsylvania (1972).

10. Tietjen, C., Michigan State University Seminar, "Sewage Disposal by Sprinkler Irrigation on 10,000 Acres of Farmland - Successes and Problems in the Past 16 Years," Federal Agricultural Experiment Station, Braunschweig, Germany (May 1973).

11. U. S. Army Corps of Engineers, Wastewater Management by Disposal on the Land, Special Report 171, Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire (1972).

12. University of Missouri Extension Division, A Guide to Planning and Designing Effluent Irrigation Disposal Systems in Missouri, MP 3373/73/1250 (1973).